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CONTENTS.

LIST OF PLATES.

ERRATA.

Page 86, Table, Russia; Grant; *for* £44,922 *read* £20,000.

,, 87, line 8, *for* one penny *read* one halfpenny.

,, 87, ,, 9, *for* a little over one-third of a farthing *read* about one-seventh of a farthing.

,, 174, Great Radiation, March 22, 1899:—

	Minimum in Screen.	Radiation on Ground.
Upper Station,	*for* 56°·1 *read* 13°·4;	*for* 42°·3 *read* 5°·7.
Lower Station,	*for* 45°·5 *read* 7°·5;	*for* 27°·0 *read* −2°·8.

,, 256, line 5 of note, *for* where *n* is a *read* where *r* is a.

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,, 255, line 6, *for* tube *read* kite.

,, 255, ,, 19, *for* cord *read* chord.

,, 258, ,, 21, *for* twenty *read* sixteen.

,, 259, Fig. 3, *for* August 26 *read* August 6.

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ROYAL METEOROLOGICAL SOCIETY

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REPORT ON EXPERIMENTS UPON THE EXPOSURE OF ANEMOMETERS AT DIFFERENT ELEVATIONS.

BY THE WIND FORCE COMMITTEE.

Drawn up by W. H. DINES, B.A., F.R.Met.Soc., and Capt. D. WILSON-BARKER, F.R.S.E., F.R.Met.Soc.

(Plate I.)

[Read November 16, 1898.]

AT a meeting of the Wind Force Committee held on June 17, 1896, it was decided to apply to the Council of the Society for a grant from the Research Fund for the purpose of making a series of experiments upon the exposure of anemometers at different elevations. The Council having authorised the necessary expenditure, five pressure-tube anemometers were obtained and placed on H.M.S. *Worcester*, under the superintendence of Capt. Wilson-Barker, by whom the observations have been taken.

The *Worcester* is a ship for training officers for the Mercantile Marine, Royal Naval Reserve, and Royal Navy. She lies in the Thames off Greenhithe, Kent, about 213 yards from the southern bank, heading west-south-west and east-north-east.[1] The river at this point is about 950 yards broad, and is bounded on the north by the Essex Marshes, so that from west-north-west by north to east the exposure is perfectly free and open, being unbroken by hills, trees, or buildings for many miles. From west by south to east-south-east, there are low hills and trees, so that the exposure is not so good; but even on this side there is nothing above the level of the mast-head within 600 yards (see Plate I.).

The anemometers were placed as follows:—

No. I. at the mizen royal mast-head, 125 feet above the water-line, and 93½ feet above the deck.

Nos. II. and III. at the ends of the mizen-topsail yard-arm, 19 feet

[1] The ship is moored, and her head points WSW (true).

laterally from the mizen-mast, 46 feet above the deck, and 77½ feet above the water-level; No. II. being on the south, and No. III. on the north side of the ship.

Nos. IV. and V. were on separate iron standards, 15 feet above the bulwarks, 20 feet above the deck, 51½ feet above the water-line, 19 feet laterally from the centre line of the ship, and 23 feet behind the mast; No. IV. being on the south side. The positions are shown in Fig. 2. It would have been better if Nos. IV. and V. could have been placed on each side of the mizen-mast instead of farther back, but the shrouds of the mast, and the shelter they would have afforded, rendered these positions unsuitable.

The anemometers, as already stated, were of the pressure-tube form,

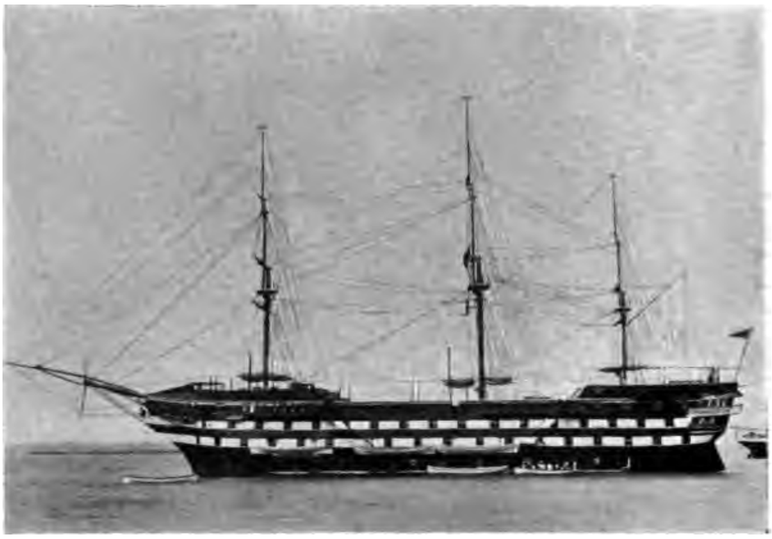


Fig. 1.—The Nautical Training College, H.M.S. *Worcester*, off Greenhithe, Kent.

the heads being similar to those in use with the recording anemometer; but for the sake of convenience in taking the observations, special arrangements were made in the mounting of the glass indicating-tubes. These tubes (*Quarterly Journal*, vol. xix. p. 19), two for each head, thus amounting to ten in all, were fixed in pairs on a wooden frame formed of lattice-work to avoid the effect of warping. The instruments were obtained from Mr. Munro, but the glass tubes were graduated simultaneously after being fixed on the frame, by Mr. W. H. Dines. Absolute similarity between the readings of all the tubes was thus obtained, and the point was further tested by connecting them all to one head, and taking observations at Oxshott for a fortnight, during which period a difference of one mile between the readings of any of the tubes was never noted.

The information given by each pair of tubes is of three kinds. First, the maximum velocity which has occurred in a gust since the last

reading. Secondly, the maximum normal velocity since the last reading. Thirdly, the present normal velocity.[1]

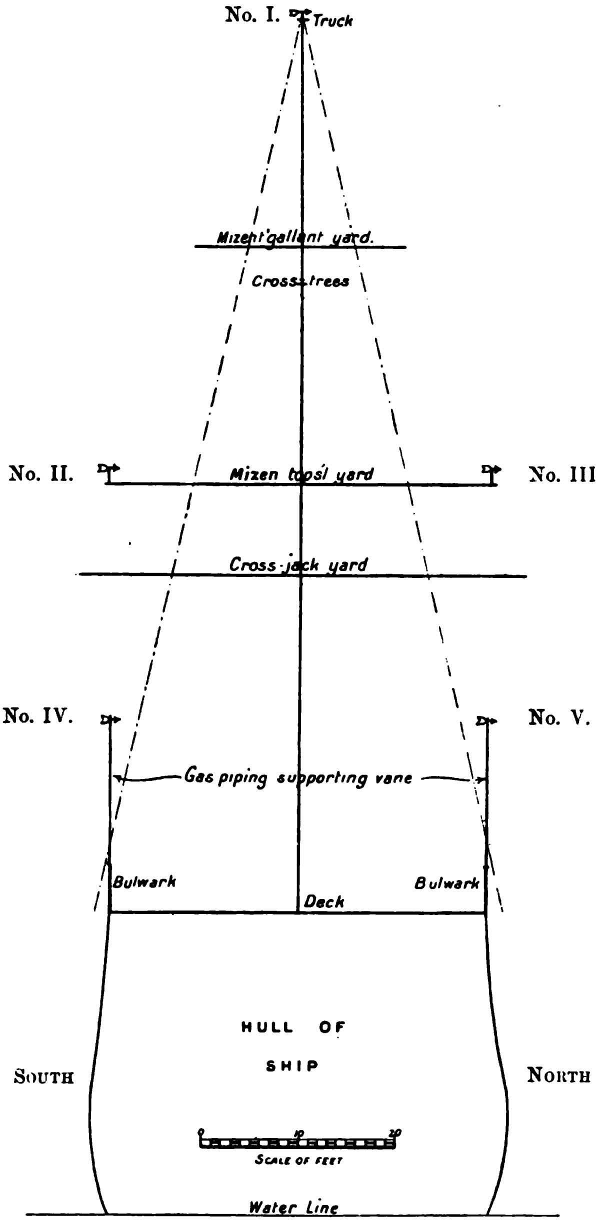


FIG. 2.—Section of Ship, viewed from astern.

[1] The term "normal" has been very aptly applied to wind velocities by Mr. R. H. Curtis. If a trace from a pressure plate or recording tube-anemometer be taken, and a red-ink line be drawn through the central parts of the space which is more or less blacked in by the perpetual oscillations of the pen, this line represents the normal velocity, which, as a rule, may be taken as fairly well representing the mean for 10 or 20 minutes.

The instruments were fitted up with great care by Capt. Wilson-Barker in the autumn of 1896, and continuous daytime observations at four-hour intervals were taken by him through the winter.

The accurate determination of low velocities with the tube anemometer depends on the accuracy with which the level of the frame containing the glass indicating-tubes is maintained; and since it is obviously difficult to ensure perfect exactitude of level on board ship, we judged it best not to include in our results velocities of less than ten miles per hour. Hence we found at the end of the winter that many observations were not suitable, and the number of observations on South-easterly and North-westerly winds was not sufficient. In the next winter, viz. 1897-98, observations were made only on suitable days, but at intervals of about two hours, and thus every opportunity of getting observations for the more unusual wind directions was seized.

The results have been worked up as follows:—

The normal velocity indicated by the mast-head anemometer, No. I., has been taken as the standard, and the normal velocity for each of the other positions has been expressed for each separate point of the compass as a percentage of it. We have an average of about ten perfect observations for each point, but the points between South and West have an excess, and for the two directions East-south-east and South-east by East there are not enough observations to give a reliable average. For very few of the other points are there less than five. The percentages have been formed thus. Each observation of Nos. II., III., etc., has been taken from the list and expressed as a percentage of the corresponding simultaneous observation of the standard, and the numbers given in the tables are the average values of these expressed percentages. For example, the 97 of No. II. for a North wind, Table I., is the mean of the following percentages,—105, 102, 100, 91, 96, 96, 95, 96, 97, 97, 96,—which represent the individual observations. Decimals have been omitted, as we do not wish to pretend to an accuracy which cannot really be attained. The example quoted above gives a fair idea of the amount of the discrepancies to be found in the individual observations.

With regard to the velocities generally registered, as previously stated, we have rejected all below 10 miles an hour. The great majority of the observations deal with velocities of from 15 to 25 miles per hour for both the present and the maximum normal. No gale of exceptional violence occurred during the period, but the three gales which did occur gave a few values over 40 miles per hour. Fifty miles for the normal and 70 for a gust have been exceeded twice, the absolute maxima being 54 and 75 respectively. The observations have not been grouped under separate ranges of velocity, but in no case do the figures show any significant change of percentage with change of velocity.

Several noteworthy points appear from this table. First, the difference between the mast-head and the yard-arm anemometers, which differ nearly 50 feet in altitude, is only 5 per cent; and this difference is caused almost entirely by winds from the more sheltered directions, the winds from North to East giving almost identical readings. Nos. IV. and V., about 75 feet below the mast-head, show a loss of $7\frac{1}{2}$ per cent, and a similar remark as above applies as to the winds from which the exposures are good and bad. These anemometers are only 15

feet above the bulwarks, which are 35 feet above the water, and represent to some extent the position of an anemometer upon a row of houses. The influence of the ship upon the readings is apparent from the table, but is not so great as might be expected.

Secondly, the influence of the low hills and trees, which are a quarter of a mile from the ship to the south and south-west, is perfectly apparent,

TABLE I.—COMPARATIVE NORMAL VELOCITY ON THE "WORCESTER."

Direction.	No. II. South or Port.	No. III. North or Starboard.	No. IV. South or Port.	No. V. North or Starboard.
	%	%	%	%
N	97	100	94	106
N by E	97	100	98	102
NNE	96	100	104	114
NE by N	97	102	96	108
NE	96	100	94	100
NE by E	102	99	98	105
ENE	101	98	95	102
E by N	104	98	96	100
E	98	101	96	99
E by S	100	98	98	96
ESE	...	...	...	...
SE by E	...	...	...	...
SE	100	99	97	96
SE by S	101	101	97	102
SSE	93	88	94	90
S by E	94	92	86	90
S	92	92	84	87
S by W	95	92	83	92
SSW	94	92	87	88
SW by S	94	93	87	90
SW	89	92	84	92
SW by W	83	91	80	90
WSW	87	92	86	86
W by S	98	90	90	84
W	95	92	89	87
W by N	95	95	92	91
WNW	94	96	92	92
NW by W	92	96	89	85
NW	92	95	93	86
NW by N	90	97	89	83
NNW	94	94	100	98
N by W	96	98	95	103
Height above river	77·5 feet		51·5 feet	

causing a difference of wind velocity with elevation which is absent where the exposure is good. Thirdly, there is a remarkable drop in the percentages for Nos. II. and IV. with a South-west by West wind, and a similar drop, though not so marked, for Nos. III. and V. with a West by South wind. Since the vessel points West-south-west a West by South wind should act on Nos. III. and V. just as a South-west by West does on Nos. II. and IV.; hence these figures, which at first sight appear as discrepancies, do really afford evidence of the general accuracy of the observations. They also show that either the disturbance caused by the ship extends to a height of 46 feet from the deck, or else that the shelter of the main-mast, which at that height is 24 inches in diameter, extends to the anemometers, which are 61 feet distant.

Table II. is similar to I., and the values differ but little from those of Table I. They are the values of the maximum normal velocity arranged in precisely the same way as the present values are arranged in Table I. It must be borne in mind that the maximum value entered under any particular point, South-west for example, did not of necessity occur with a South-west wind, since the maximum may have occurred some time before the observation was taken and the wind may have changed in the

TABLE II.—COMPARATIVE NORMAL MAXIMUM VELOCITY ON THE "WORCESTER."

Direction.	No. II. South or Port.	No. III. North or Starboard.	No. IV. South or Port.	No. V. North or Starboard.
	%	%	%	%
N	98	98	94	105
N by E	97	98	100	103
NNE	100	112	102	108
NE by N	97	100	91	106
NE	97	96	92	103
NE by E	102	99	98	105
ENE	102	97	96	101
E by N	104	98	98	100
E	96	96	93	93
E by S	101	97	100	94
SE	99	88	93	90
SE by S	100	98	98	100
SSE	96	94	98	94
S by E	94	92	88	88
S	93	92	84	84
S by W	94	91	80	91
SSW	94	93	87	90
SW by S	94	92	87	89
SW	89	90	84	89
SW by W	85	93	80	89
WSW	88	89	84	85
W by S	98	93	90	85
W	94	92	87	86
W by N	95	95	92	92
WNW	94	97	91	92
NW by W	93	96	90	85
NW	92	97	93	85
NW by N	90	100	90	85
NNW	96	98	102	100
N by W	97	100	96	110
Height above river	77·5 feet		51·5 feet	

interval. Table II. is also of necessity based on higher velocities than Table I.

Table III. gives the corresponding percentages for the maximum velocity in the gusts. There is more uncertainty about these figures; for while the length of the compo tube between the head and the glass indicating-tubes cannot in the slightest degree influence the mean velocity recorded, it certainly may alter the maximum, and the same may be said of a sharp bend or contraction in the tube. The figures, however, do not differ greatly from those of the other tables, and this is especially the case for those points for which there are plenty of observations. The actual figures show that the gustiness of the wind is much the same at the mast-head as it is 20 feet above the deck, but also that winds from points with a good exposure are very much steadier than those from

points with a bad exposure. Taking the average, the maximum velocity recorded in a gust by this particular form of instrument has been 50 per cent above the normal velocity, but the percentage varies from about 30 per cent at the points with a good exposure, to 70 to 80 per cent with the South and South-westerly winds.

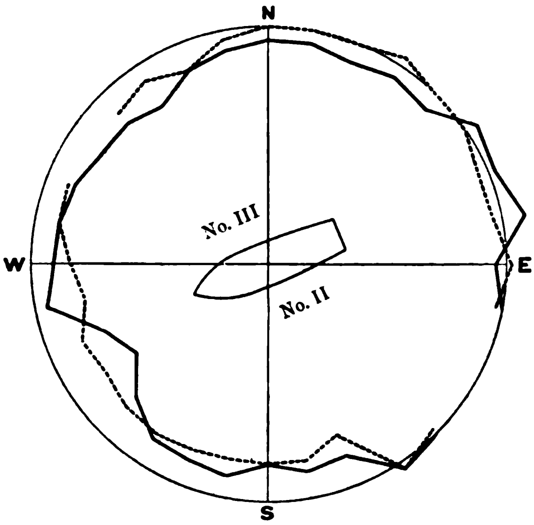
TABLE III.—COMPARATIVE MAXIMUM VELOCITY OF GUSTS ON THE "WORCESTER."

Direction.	No. II. South or Port.	No. III. North or Starboard.	No. IV. South or Port.	No. V. North or Starboard.
	%	%	%	%
N	96	98	87	103
N by E	102	104	98	117
NNE	100	93	95	106
NE by N	100	96	88	100
NE	97	97	88	99
NE by E	101	99	97	101
ENE	102	97	93	97
E by N	101	96	95	96
E	96	93	86	88
E by S	105	104	97	97
—	—	—	—	—
SE	99	89	91	93
SE by S	96	84	90	95
SSE	101	91	94	97
S by E	100	92	91	90
S	95	88	84	87
S by W	90	83	87	88
SSW	95	90	88	90
SW by S	101	96	90	98
SW	90	89	90	93
SW by W	89	95	84	91
WSW	91	92	83	88
W by S	95	95	85	93
W	93	94	87	94
W by N	95	94	89	96
WNW	98	99	90	99
NW by W	96	89	91	102
NW	96	103	93	106
NW by N	96	106	94	110
NNW	96	102	88	103
N by W	100	102	87	109
Height above river	77·5 feet		51·5 feet	

The results of Table I. are shown graphically by the diagrams, Figs. 3 and 4. The percentages are marked off proportionally on radii of a circle, the direction of the radii giving the corresponding directions of the wind. The line of the ship being East-north-east and West-south-west, the similarity of the curves for the two lowest anemometers, notably in the north-east quadrant, is very noticeable.

In addition to the observations made on the *Worcester*, four anemometers of a similar kind were fixed over Mr. Dines' house at Oxshott, and read at frequent intervals during the winter of 1896-97. The house is approximately 40 feet by 40 feet and 32 feet high, having a small flat, 12 feet square, in the centre of the roof. The highest anemometer, A, was 39 feet above the roof and 71 feet from the ground; the second, B, was 18 feet above the centre of the roof and 50 above the ground; the third, C, and fourth, D, were 9 feet

above the roof and 41 feet above the ground, but were placed, C on

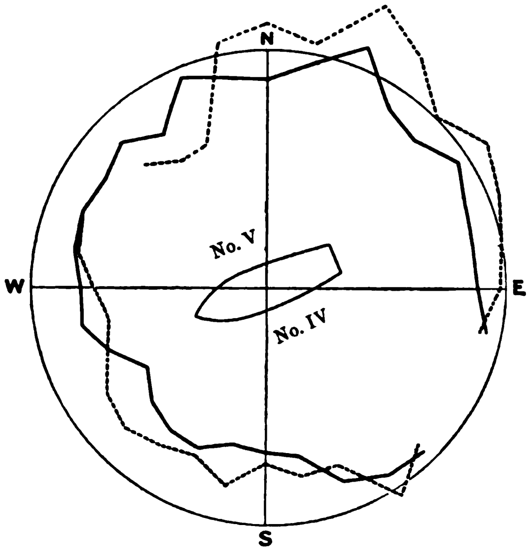


N°II. South side of Ship. ————————

N°III. North - - - ....

FIG. 3.

the north-east, and D on the south-west side of the flat, the lateral distance between them thus being 12 feet. In this case there is a



N° IV. South side of Ship. ————————

N° V. North - - - ....

FIG. 4.

good exposure from north-north-east through east to south-east; there

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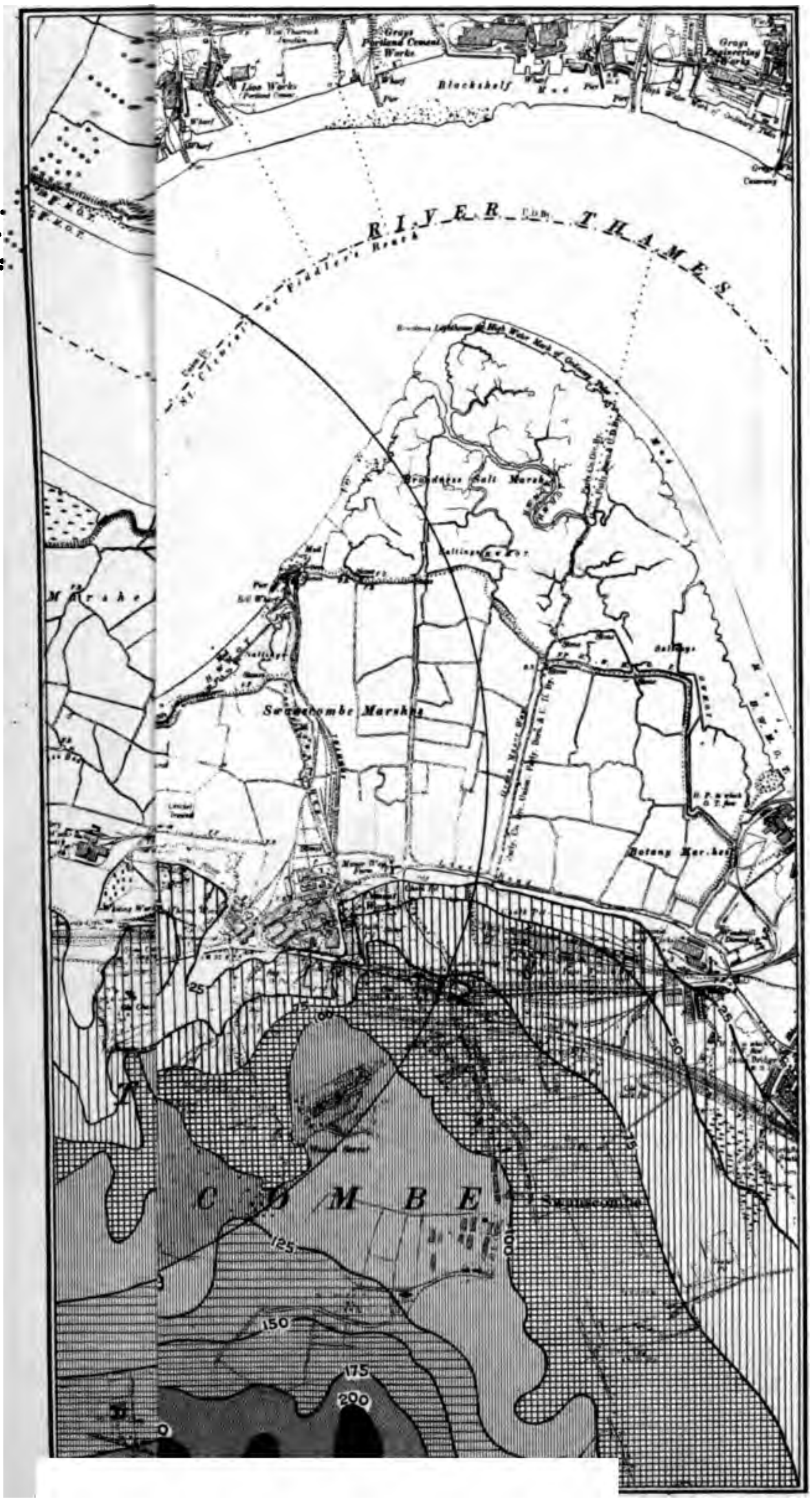


are trees as high as the ridge of the roof and about 100 yards distant to the south and south-west; there is a gap from west-south-west to west by north through which hills 12 miles distant can be seen, but on the north-west there are trees, whose tops are level with the highest anemometer, about 30 yards distant; and to the same quarter, north-west, there is a hill some 50 feet higher than the house, about 200 yards

TABLE IV.—Comparative Velocities over Dwelling-house.

Direction.	B.			C.			D.		
	Normal.	Maximum Normal.	Maximum Gust.	Normal.	Maximum Normal.	Maximum Gust.	Normal.	Maximum Normal.	Maximum Gust.
	%	%	%	%	%	%	%	%	%
N	77	83	88	67	71	74	69	79	85
N by E	76	77	90	63	62	76	69	71	85
NNE	77	80	82	69	77	80	75	80	92
NE by E	80	84	86	80	86	87	77	82	95
NE	94	96	94	93	96	90	86	87	101
NE by E	94	96	90	89	91	92	82	86	97
ENE	93	92	87	90	90	95	80	83	98
E by N	...	...	...	...	...	...	...	...	...
E	96	97	90	100	97	92	89	90	96
E by S	94	100	93	94	100	93	94	94	96
ESE	90	91	92	95	93	86	93	93	90
SE by E	91	88	93	91	88	97	94	91	98
SE	92	90	92	89	87	93	93	91	97
SE by S	93	91	91	91	87	93	93	88	92
SSE	90	85	89	90	83	89	86	77	87
S by E	90	88	87	87	84	89	80	78	91
S	80	78	87	76	78	86	70	74	88
S by W	73	77	90	71	76	85	65	70	87
SSW	81	81	87	74	74	84	70	69	85
SW by S	79	81	88	68	71	83	68	69	87
SW	82	83	89	68	71	83	68	71	89
SW by W	82	82	92	71	71	87	69	69	88
WSW	86	86	91	77	76	89	74	74	93
W by S	85	85	93	76	78	89	75	77	88
W	82	81	82	79	80	85	78	79	81
W by N	87	86	93	77	76	90	78	78	90
WNW	71	80	82	71	77	81	71	76	82
NW by W	...	...	...	...	...	...	...	...	...
NW	...	...	...	...	...	...	...	...	...
NW by N	...	...	...	...	...	...	...	...	...
NNW	73	76	78	64	66	70	67	74	78
N by W	...	...	...	...	...	...	...	...	...
Height above ground	50 feet			41 feet.					

distant. The results are given in Table IV., the highest anemometer being taken as standard.

The velocities for this table are about 10 per cent lower than for the *Worcester*, but a maximum for a gust of 79 was recorded, though in a different gale from that which gave 75 on the *Worcester*. In this case, although the differences of elevation are slight compared with those on the *Worcester* the percentage differences are considerably in excess. The effect of a bad exposure is very marked, and the results agree with those of the *Worcester* in showing that the wind force increases rapidly with elevation when there is a bad exposure. It must be remembered

that the ship presents a much greater obstacle to the wind than the house, but on the other hand the anemometers were much closer to the house than those on the *Worcester* were to the ship.

The Committee are of opinion that the general facts deducible from the preceding observations and bearing on the situation of instruments for testing wind force are: (1) that they must have a fairly clear exposure to be of much value; and it would appear that for a mile at least all round there should be neither hills, nor anything else higher than the position of the instruments. (2) That on a ship the results may be considered fairly accurately determined by having the instrument 50 feet above the hull, but that on land it will be necessary to carry the instrument to a height to be determined entirely by the local conditions. (3) That no other form of anemometer offers such advantages as the pressure-tube, from the fact that it can be run up and secured easily at 50 feet or more above a building, and that the pipes and stays can be so slight that they neither offer resistance to the wind nor cause any deflecting currents.

DISCUSSION.

The President (Mr. F. C. Bayard) said the Society was indebted to Mr. Dines and Capt. Wilson-Barker for the labour they had undertaken in the preparation of this Report, and as the observations extended over two years, the task had been no light one. It appeared, however, from the conclusion which the authors had deduced from the observations, that the selection of a good exposure for an anemometer presented difficulties hitherto unthought of.

Mr. E. Mawley concurred with the President's remarks as to the thanks of the Society being due to the authors for their excellent work. The Report was one of special interest, as it marked the first time that a grant had been made from the Research Fund for experimental purposes. The results were in his opinion very disappointing. This was in no way due either to the Wind Force Committee, or to Mr. Dines and Capt. Wilson-Barker, under whose care the investigation had been so carefully planned and carried out, but rather to the unsuitable character of the site selected. And yet he did not think that any one who had visited the *Worcester* could have foreseen that the position was not as open and as free from disturbing influences as could well be desired. The wind was a proverbially fickle element; but not until this Report appeared had he appreciated the extent of its fickleness, or how air-currents could be deflected, to the extent indicated by these experiments, by objects hitherto regarded as too low and too distant to be of any great moment. He had been sanguine enough to anticipate that, with the help of the Dines pressure-tube anemometer and the information that would be given in this Report as to the rate of increase in wind-force with elevation, it would be possible to set up anemometers all over the country, the indications of which would be almost as comparable as those now obtained in respect to temperature and rainfall. He should have thought that anemometers placed at a height of between 70 and 80 feet above the river, like Nos. II. and III. on the *Worcester*, and with such an apparently unobstructed exposure, would give reliable values; but it seemed from the Report that the results were only trustworthy from points between north and east. And even when the mean pressures from those reliable points were alone taken, they were almost identical with those given by the anemometer at the mast-head—125 feet above the river. Indeed, the Report did not in the least

confirm the generally accepted idea, and, he still thought, the true one, that the wind increased with elevation, but rather contradicted it, and especially anemometer No. V. It seemed that we had now as good an anemometer as could be wished, but that we were still as much in the dark as ever as to where it should be placed to give satisfactory results. He was afraid very few, if any, of the anemometers in use at the Society's stations would be found to meet the requirements set forth by the Committee at the end of this Report. He thought that, with the experience gained by the experiments on the *Worcester*, it might be possible to devise others elsewhere which would serve to set at rest the vexed question of anemometer exposure, and at the same time show the comparative strength of the wind at different heights above the ground.

Mr. J. K. LAUGHTON said that the results tabulated were most strange. It was not only that the lower instruments recorded a greater velocity than the higher, but that those on the same level, at a distance of only a few yards from each other,—as in Table I., columns 4 and 5,—differed extremely. Probably there was some explanation of this; but, as the Table stood, it was incomprehensible.

Mr. E. D. ARCHIBALD thought that if the results of the Committee's work appeared disappointing, the observations ought yet to be regarded as instructive in showing how many disturbing elements occur to prevent the correct registry of the wind near the surface. In his kite-suspended anemometer experiments some years back he began at the level where these experiments left off, viz. about 100 feet above the surface; and, personally, he did not think that, except in very flat, bare districts, or at sea, any exposure at lower heights than this gave results which really represented the true velocity of the wind. In the present case it appeared, from the remarkable and almost progressive change of law which took place between the values Nos. III. and V. between north-north-east and west by south, that the anomalies were chiefly due to the exposure, and affected either by the lie of the ship or the contour of the surrounding country. From the map it appeared that there was high land to the south-west of the ship, which might have deflected the air-currents. Of course the results of the present investigation in no way affect the validity of the rule established by his anemometer experiments in showing that the average velocity of the wind increases with the height above the surface, since they were evidently vitiated by the operation of unknown sources of irregularity which disappeared at the higher levels.

Mr. F. J. BRODIE remarked on the severity of the conditions suggested for the proper exposure of anemometers. He could scarcely conceive that a high tree at a distance of half or even a quarter of a mile would have any appreciable effect on the indications of the instrument. The sheltering influence of hills would, of course, depend entirely on their height, and their distance from the station. He feared that at very few observatories in this, or perhaps in any other, country would the position of the anemometer pass so rigorous a test as that laid down by the Committee.

Mr. R. H. CURTIS thought there were several points of considerable interest in the paper. First, there was the effect which appeared to be due to the exposure of the anemometers with reference to the surrounding country. The winds which came from the north and east, and which blew over a long stretch of level land before they reached the river and the ship, gave results which were materially different from those given by winds from the opposite quarters, and which, after traversing an undulating country, were poured down into the wide river-way over the sides of hills relatively high as compared with the lower anemometers, and close to the shore and the ship. It was certain this descent of the mass of moving air must set up large eddies and whirls, which would not have time to straighten themselves out before they reached the

instruments; and to these eddies, he believed, was due the fact, clearly shown in Fig. 2, that the yard-arm anemometers gave a lower percentage of the force at the mast-head when the wind blew from Westerly points, than they did with Easterly winds of similar strength. It was also interesting to note that with unobstructed winds the force at the yard-arm, 40 feet above the bulwarks of the ship, was practically the same as at the mast-head, 50 feet higher up; and this bore out the view he had expressed before, that in a suitable locality an anemometer 40 feet above the ground—or, in the case of towns, above the general level of the house-tops, which might be taken as the same thing—would give the true wind-force, free from the effect of the friction of the ground; and he quite endorsed the remark in the paper as to the value of the pressure-tube anemometer for easily securing this condition. The results obtained from the lowest pair of anemometers showed that 15 feet was much too low to get rid of the influence of the hull of the ship; but it was remarkable here that the anemometer on the starboard side usually gave the highest percentage, not only when that was the windward, but also when it was the leeward side of the ship, and this, he thought, was another result of the eddies he had referred to. That, under certain conditions, the lower instrument should indicate more wind than was indicated at the mast-head was to be expected, and was quite in keeping with the results he had himself obtained at Holyhead, and which formed the subject of a paper he read before the Society in 1896; the effect of the obstruction offered by the hull of the ship to the moving air was to throw it upwards, so that for some distance above the obstruction there would be more than the proper amount of air due to that level, and the observations made it clear that in this case at least a height of 15 feet above the obstruction was not sufficient to surmount the excess it would cause.

Mr. C. Harding said that the Report was an honest endeavour to advance our knowledge of the subject, and, in his opinion, it had fulfilled its object. He was rather surprised no correction had been made for elevation of instruments. It also struck him that an average of 10 observations for each point (in some cases only 5) was scarcely enough to establish a reliable average. He should also like to ask if Capt. Wilson-Barker had taken the observations himself, or were the cadets under his charge responsible for any of the readings?

Mr. G. J. Symons thought that the *Worcester* deflected winds from certain points. It was very remarkable that a hill a mile distant, and only 175 feet in height, or 50 feet higher than the instrument at the mast-head of the *Worcester*, should be responsible for the discrepancy with winds from the southern quarter. If so slight a gradient affected the records, it boded ill for anemometers in general. He did not think there could be any improvement in the working arrangements, but an instrument or two might with advantage be placed at the other end of the ship, which would to some extent gratify Mr. Harding's desire for more records.

Mr. J. K. Laughton said that the mere banking up of the air against the ship's hull did not seem to explain the remarkable discrepancy of the lower readings. From the position in which the ship was moored, the discrepancy, due to this cause, would be greatest for North-north-west winds, which strike the hull nearly at right angles. Instead of that, it is greatest with North-north-east winds; the reason for which did not appear.

Capt. Carpenter said that with regard to the influence of land in directing the course of the wind, it was a remarkable fact that in the case of cyclones at sea, on their coming in contact with land,—even that of insignificant altitude,—they would deviate from their path, and often disperse.

Mr. R. Inwards thought the *Nore*, or other of the lightships round the coast, would be more suitable for the investigation as regards exposure than the *Worcester*.

Capt. D. WILSON-BARKER, in reply, referring to the seeming discrepancy with winds from a southern quarter, said that the winds were extremely unsteady and gusty from that quarter, and he could only attribute the fact to the comparatively high ground in that direction. With regard to Mr. Symons' suggestion of corroborative experiments being carried out, he thought the foremast might be used. All the observations had been made by himself. He also was surprised to find contradiction of the accepted theory of increased velocity with elevation, which was perhaps after all a superstition. He agreed with several speakers that deflection of the wind by the hull of the ship might to some extent affect the records of the lower anemometers.

Mr. W. H. DINES said that no doubt the results were to some extent disappointing, but still the percentage differences were not after all so very great. The 114 per cent (Table I., N.N.E., No. V.) referred to by Mr. Laughton was probably a discrepancy, which would disappear were there a greater number of observations, but the increased percentages of the lower anemometers for North-east winds were certainly due to the disturbing action of the ship. He could not agree with Mr. Symons about the hills to the south not influencing the results. Not only on the *Worcester*, but also at Oxshott, the percentages of the lower anemometers began to fall off at the precise point at which the hills began to afford shelter, and at the same points the character of the winds changed, and they became gusty. With regard to Mr. Symons' question about the tube anemometer, he could state positively that it was not necessary for the wind to strike the head exactly perpendicular to the mouth of the open tube. When experimenting on the large whirling machine at Hersham, he had tried and rejected many forms of opening on this account, but the tube anemometer admitted of a variation of about 20° without appreciable effect. In reply to Mr. Archibald, he said that the heads of the five anemometers were precisely alike, certainly to one-thirty-second part, and probably to one-hundredth part, of an inch, and the precautions which were taken to ensure similarity in the glass tubes were described in the Report.

COMPARISON OF ESTIMATED WIND-FORCE WITH THAT GIVEN BY INSTRUMENTS.

By CAPT. D. WILSON-BARKER, F.R.S.E., F.R.Met.Soc.

[Read November 16, 1898.]

IN working out the observations on which the Report of the Wind Force Committee is founded, it occurred to me that it would be interesting to compare the estimated force, not only with the results obtained from the Dines instruments, but also to show comparison between the Dines instrument, with estimates according to the Beaufort scale, and the reading of hand anemometers.

In 1883 I had the honour of laying before this Society some results of comparisons made at sea between the estimated force of the wind and that recorded by two hand anemometers. Since that time, during a voyage in a sailing-ship from England, *via* Australia, to San Francisco, and thence home, I took a number of observations, which have not till now been worked up.

I think it may be interesting to the Fellows to see the results of all these observations set forth.

Before, however, comparing the results obtained by instruments with estimates, it must be remembered that a seaman judges the general force of the wind on the average, and that there may be considerable variations not noted by him, which would be represented on a recording instrument, but which could not be shown on an ordinary hand instrument, which reads only actual velocity of wind for the short interval for which it is exposed.

It is necessary to keep this in mind, as it will be seen in the table that there is considerable range in the readings of the anemometers. A seaman will give the average estimate of the wind-force, but it must be remembered that he will not include any but ordinary undulations in the force—unusual increments, such as are caused by squalls, are usually made the subjects of a special note.

Again, it must be borne in mind that no class of men is so constantly exposed to the weather as sailors, and that they unconsciously acquire a habit and knowledge of it which it is difficult for any one not so circumstanced to gain.

It may be argued that in the modern fast steamers there will be considerable difficulty in applying the old rules of Sir Francis Beaufort, or even the modern rules for sail-spreads as modified by Captain Toynbee.

I do not think the argument holds, for, in my opinion, the sea itself forms a more valuable index to a fairly correct estimate of the wind, both as to its force and direction, than does the amount of sail spread. At the same time, I think that it would be extremely valuable on board ship if a simple form of anemometer could be set up.

The three hand anemometers which I exhibit are all available for these purposes. The objection to them is that they have to be carried about.

It appears perfectly possible to fit up a modification of the Dines pressure-tube instruments,[1] which would be serviceable not only for use on board ship, but also in small observatories on shore—an instrument that could be read off on some form of dial; and would show at the moment of observation the velocity of the wind. The adoption of such a plan with properly calibrated instruments would ensure, at any rate, a correct comparison of wind-force, even if it did not show the absolute velocity.

I have dealt in another paper[2] with the effect of the ship's motion through the water, and method of correcting the same.

I am persuaded of the necessity for accurate wind observations taken at sea; and I have urged, over and over again, that our only hope of deducing meteorological laws is by correct and systematic observations taken at sea; because the immense area of the ocean and its uniform conditions offer especial facilities for making such observations, and because, so far, very little of really useful knowledge has been derived from the mass of information stored upon the shelves of observatories.

There are numbers of vessels at sea engaged in the work of surveying, laying and repairing telegraph cables, etc.; these vessels are eminently

[1] Since this paper has been read, Mr. Dines has prepared an exceedingly simple and ingenious apparatus for this purpose.

[2] "Notes on taking Meteorological Observations at Sea," *Quarterly Journal Roy. Met. Soc.*, vol. xiii. p. 185.

adapted for scientific work, because of their opportunities for observation. I cannot help feeling that some method might be found to induce officers in these ships to be scientific observers, not only in the interests of Meteorology, but also for the forwarding of other sciences, without in any way interfering with their proper work.

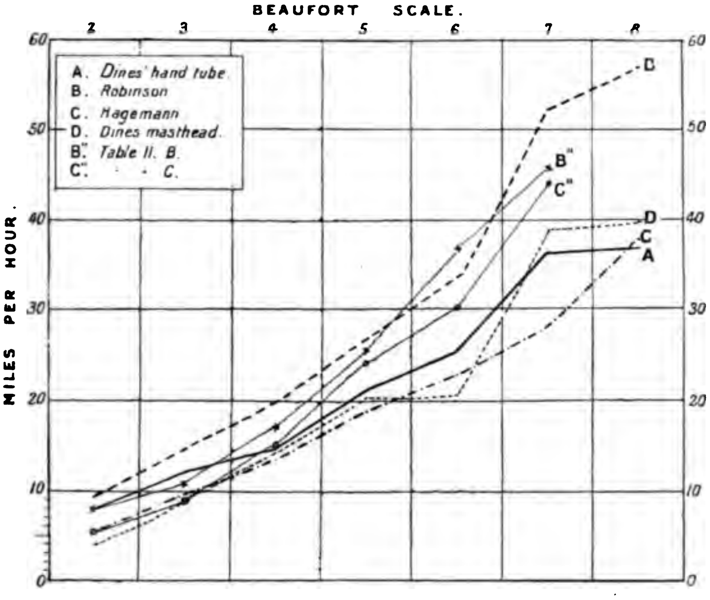
The instruments used were as follows:—

A. Dines hand pressure-tube anemometer, kindly lent me by Mr. Casella.

B. Robinson hand cup anemometer, modified by Mr. R. L. J. Ellery, C.M.G., F.R.S., late Government Astronomer of Victoria.

C. Hagemann anemometer, modified by Mr. Ellery.

D is the mast-head Dines pressure-tube anemometer on the *Worcester*.



It will be seen that B is a mechanical gauge: the others are pressure-vacuum gauges.

Table I. gives the results of observations taken on board the *Worcester*. Table II. gives the results of observations taken at sea. The diagram gives the results expressed in a graphic manner. These tables will explain themselves.

It will be observed that the Hagemann anemometer gives really the most satisfactory results.

In some cases the number of observations taken have not been sufficient to allow the results to be considered conclusive evidence.

The estimated force from the Beaufort scale has been used to compare the observations with, but it is obvious that any of the others might have been taken as the standard.

So far as I am aware, no attempt has hitherto been made to make any comparison on board ship in a similar manner to this; and I trust that these results may be of interest—especially when taken into con-

TABLE I.—Comparison of Anemometer Readings and Estimated Force on the "Worcester."

Force . .	2			3			4			5			6			7			8		
Velocity by Beaufort Scale.*	factor 3 9		factor 2.2 7	factor 3 14		factor 2.2 10	factor 3 19		factor 2.2 14	factor 3 26		factor 2.2 19	factor 3 34		factor 2.2 25	factor 3 42		factor 2.2 31	factor 3 50		factor 2.2 37
Anemometers used.	No. of Observations.	Range.	Mean No. of miles per hour.	No. of Observations.	Range.	Mean No. of miles per hour.	No. of Observations.	Range.	Mean No. of miles per hour.	No. of Observations.	Range.	Mean No. of miles per hour.	No. of Observations.	Range.	Mean No. of miles per hour.	No. of Observations.	Range.	Mean No. of miles per hour.	No. of Observations.	Range.	Mean No. of miles per hour.
A	4	4–10	8·0	42	6–17	12·1	64	10–22	14·6	33	16–28	21·1	18	19–33	25·4	3	30–44	36·3	1	...	37
B	4	5–14	9·2	42	9–23	14·4	64	9–29	19·7	33	18–36	26·7	18	21–48	33·7	3	41–66	52·3	1	...	57
C	4	3–10	5·5	42	5–16	9·5	64	7–20	13·4	33	14–26	18·6	18	17–34	22·8	3	26–31	28·3	1	...	38
D { a	4	8–20	12·0	42	5–22	11·5	64	7–31	15·2	33	14–36	22·8	18	13–36	20·8	3	32–44	39·3	1	...	53
D { b	4	2–6	4·0	42	0–22	8·7	64	3–30	14·1	33	9–36	20·3	18	10–40	20·5	3	35–45	39·0	1	...	40

A = Dines hand pressure-tube anemometer. B = Robinson-Ellery hand cup anemometer. C = Hagemann-Ellery anemometer.
D = Dines pressure-tube at mast-head of *Worcester*—*a*, maximum reading of damped tube; *b*, reading of undamped tube.

* From *Hints to Meteorological Observers*, by W. Marriott, F.R.Met.Soc.

TABLE II.—Comparison of Anemometer Readings and Estimated Force at Sea.

Force. Beaufort Scale.	2			3			4			5			6			7		
Anemometers used.	No. of Observations.	Range.	Mean No. of miles per hour.	No. of Observations.	Range.	Mean No. of miles per hour.	No. of Observations.	Range.	Mean No. of miles per hour.	No. of Observations.	Range.	Mean No. of miles per hour.	No. of Observations.	Range.	Mean No. of miles per hour.	No. of Observations.	Range.	Mean No. of miles per hour.
B	27	5–12	8	116	3–26	$10\frac{3}{8}$	248	10–26	17	20	18–35	$25\frac{3}{4}$	3	34–39	37	1	...	46
C	27	4–9	$5\frac{1}{2}$	116	4–20	$8\frac{3}{4}$	248	8–24	$14\frac{3}{8}$	20	17–31	22	3	28–34	$30\frac{1}{4}$	1	...	44

sideration with Mr. Curtis's valuable paper[1]—to those who are unable to take such sets of observations, and that they may assist in bringing to some satisfactory conclusion the present chaotic state of affairs.

To attain this end, I would propose that all reference to sail set be left out, and the numbers be reduced to 9 units as in Table III., in which also the sea equivalents are given. This, I think, would meet all requirements, and would enable us to retain a modified Beaufort scale, which is, after all, very handy where self-recording instruments are not in use.

TABLE III.—WIND VELOCITY AND CORRESPONDING SEA DISTURBANCE.

Beaufort Scale.	Description of Wind.	Velocity in Miles per Hour.	Sea Disturbance.	Height of Waves in Feet.	Description of Sea.
0	Calm	0	0	0	Calm.
1	Light airs	3	1	0–1	Very smooth.
2	Light breeze	9	2	1–2	Smooth.
3	Moderate breeze	16	3	2–3	Slight.
4	Fresh breeze	24	4	3–5	Moderate.
5	Strong breeze	34	5	6–10	Rather rough.
6	Gale	42	6	10–18	Rough.
7	Strong gale	55	7	18–28	High.
8	Hurricane	70	8	28	Tremendous.

DISCUSSION.

The President (Mr. F. CAMPBELL BAYARD) said the thanks of the Society were due to Capt. Wilson-Barker for his paper. He (Mr. Bayard) thought that the question of deflection of the wind would more than ever have to be considered, the hand instrument being held in close proximity to the ship's side. He did not think observations with the hand anemometer on the deck were comparable with the Dines pressure-tube instrument at the mast-head of the *Worcester* at a height of 125 feet.

Mr. C. HARDING said that in the *Meteorological Log* the column for wind-force was headed "at time of observation," and was not an estimate over any period. Thanks to Admiral Sir William Wharton, F.R.S., of the Hydrographic Office, on every Admiralty surveying vessel that put to sea systematic observations were taken. He (Mr. Harding) thought, from the illustration shown on the screen of the method of holding the hand anemometer, that the body itself would have a serious effect on the indications of the instrument. Capt. Watson, an observer for the Meteorological Office, had conducted a comparison with the hand anemometer and Mr. Scott's equivalents of the Beaufort notation, and, as a result, had proclaimed the latter to be no more than a mile out. With reference to Capt. Wilson-Barker's suggestion of reducing the Beaufort scale to 9 units, he should be sorry to see this generally adopted.

Mr. R. H. CURTIS said he was obliged to view all anemometrical observations made at sea, on board ship, with a good deal of suspicion, not only because of the great difficulty of making a proper allowance for the speed and direction of the ship, but also because of the effect upon the anemometer of the hull and rigging of the ship itself. The importance of this latter point had been well shown in the paper on the *Worcester* experiments to which they had just listened; and his mind was not at all relieved on the matter by the illustrations of the method adopted for exposing the anemometers which Capt. Wilson-

[1] *Quarterly Journal Roy. Met. Soc.* vol. xxiii. p. 24.

Barker had shown them upon the screen. In addition to this, there was the further question of the reliability of the particular instruments which Capt. Wilson-Barker had used; for nothing had been said as to the way in which their constants had been determined, or as to how their indications had been connected with those of the anemometers used on board the *Worcester*. We did know, however, from the previous paper, that if the mast-head values were used it would be very unsafe to compare them with estimations based on what could be felt of the wind on deck, or even seen of its effects on the river close at hand. To the alteration in the number of units in the scale, which Capt. Wilson-Barker had proposed, he also had a great objection; for what was required was a reduction in the number of scales already in use, rather than the addition of another to the already too long list. The Beaufort scale of 13 units, 0 to 12,—which, by the way, was a thing altogether apart from the *sail equivalents* for the same units,—had been shown by experience to be the most useful. There might be a difficulty in sufficiently discriminating in words between the different units, and the distinction between the various grades of gales might not have been well expressed; but there was no doubt that there were very real differences in the strength of the wind after gale-force had been reached, and these differences were properly expressed by the upper numbers of the scale: "7" was a gale, but "10" was a gale of quite another quality, and "12" was a phenomenon which, although happily it was not often witnessed on our coasts, was yet not unknown there, and at all events had to be provided for in a scale which, like the Beaufort, was intended for use everywhere, and professed to embrace the extreme range of wind-force.

Capt. A. CARPENTER remarked that it was usual to keep a meteorological register on board surveying vessels, but often the observers had no meteorological training whatever, which was a great disadvantage. The effect of the wind on the surface of the sea—a trustworthy method of estimating wind-force, and commonly used by seamen—was not possible in the case of the *Worcester*. It was not usual on board ship to observe the wind-force at a given moment and call it the wind-force for that hour. A sudden squall or gust at the time of regular observation would not be used, but the general force entered in the log. Capt. Wilson-Barker might try the effect on an anemometer placed at the end of a horizontal spar rigged out across the bulwarks. There must be a certain distance out at which the cushioning of the air against the ship's side is no longer appreciably felt, and a result comparable with that at the mast-head would be obtained. It would be interesting to get some observations on this point, especially when the wind was from North-north-west or abeam.

Mr. E. MAWLEY considered that sailors might be left to estimate wind-force in accordance with the Beaufort scale; but that to observers on land a simple form of hand anemometer would be of great assistance, and would be likely to result in more comparable observations than the present method of estimation. It, however, appeared from the paper that it would be necessary for all observers to use the same type of instrument. His own plan in estimating the force of the wind was to observe the rate at which the cups of his Robinson anemometer on the top of the house were moving, instead of depending on the movements noticeable in the branches of trees and other similar objects.

Mr. W. H. DINES said that he had received the following piece of information from Mr. Rotch; when he (Mr. Rotch) last crossed the Atlantic he had taken with him a portable pressure-tube anemometer, and he had found that on a perfectly calm day, when used at the extreme front of the vessel, it indicated the velocity of the ship, as of course it ought to do, but that he could not obtain this result on any other part of the deck.

Capt. D. WILSON-BARKER, in reply, said that his idea was not to make the comparison run as smoothly as possible, but rather to show up likely discrepancies

in order that we might in future better know how to avoid them. With reference to his suggestion of limitation of the Beaufort scale, he thought confusion was often caused by the various modifications of gales, such as "moderate gale," "strong gale," and "whole gale," when "gale" and "strong gale" would answer all ordinary requirements. A hurricane, of course, was an intensified form of gale, but he thought the term "storm" for force 11 in the Beaufort scale slightly misplaced. With regard to Capt. Carpenter's remarks on the effect of wind on the surface of the water, he of course meant it to apply to waves in the open sea. He thought Capt. Carpenter's suggestion as to an anemometer at the end of a spar held out from the ship's side a very good one. There is no difficulty in making a proper allowance for the speed and direction of the vessel. The hand instruments used had been carefully set at the Melbourne Observatory.

He entirely disagreed with Mr. Curtis that these are the real differences in force which he contended for, and he was quite sure, with the possible exception of an open common or heath, that it is impossible to estimate these possible differences on land. All the observations were taken entirely by himself. He did not think we should be deterred from making alterations in anything, however old it might be, if by so doing an improvement could be made ; and he contended that simplification, within certain limits, would produce better results. At the same time, while he only put forward the revised scheme as a suggestion, he was strongly of opinion that every effort should be made to simplify scales and to make them comparable : in this case it became comparable with that in use for wave disturbance.

THE TORNADO AT CAMBERWELL, OCTOBER 29, 1898.

By WILLIAM MARRIOTT, F.R.Met.Soc.

[Read November 16, 1898.]

On opening the newspaper on Monday morning, October 31, I was greatly startled to learn that a tornado had swept over Camberwell on the previous Saturday night and caused a great deal of damage. The following account is taken from the *South London Observer* :—

Henceforward Camberwell will boast amongst its numerous claims to historical celebrity that it holds the record for cyclonic disturbance, and has experienced a meteorological phenomenon which is practically unique in metropolitan annals, and is certainly more in accordance with the climatic conditions of the West Indies or Central America than with those usually obtaining in the vicinity of the Green.

What may be justly described as the most terrible wind storm that has ever been experienced in the metropolis broke over Camberwell and its immediate vicinity on Saturday night, causing many personal injuries and great destruction of property. At half-past nine in the evening a wind sprang up, which in a few minutes had so increased in force that foot passengers were compelled to seek a hasty shelter. The wind raged with great fury, and tore huge coping-stones and slates from the roofs of shops and houses. Nearly every building in the vicinity bears traces of the hurricane. Street lamps were twisted like corkscrews, huge trees were uprooted and literally hurled across the tramway lines, scaffoldings were demolished, and electric street lamps torn from their supports. Curiously enough, the storm seems to have only affected an area of about a half-mile square, for while the streets in the neighbourhood

of Camberwell Green were strewn with slates, bricks, and glass, and in many cases doors were completely wrenched from their hinges, no serious damage was done in the surrounding districts of Kennington, Walworth, or Loughborough.

The whirlwind appears to have first swept down Denmark Hill, and thence rushed, with a noise resembling the roar of an express train, round the corner into the Camberwell New Road, where it seems to have divided its work of destruction between buildings in the Station Road and property immediately opposite in the direct line from Camberwell Green. Then in some inexplicable way the cyclone veered round into Baldwin Crescent, a thoroughfare lying away from the main road, west of the railway, where it spent its final fury in wrecking the roofs and top-storeys of some half-dozen houses.

Starting from the corner of the Metropole Theatre, it appears that the full force of the wind gust, which accompanied a deluge of rain and lasted something less than a couple of minutes, was chiefly felt on the parade side, where the massive lamp standards were broken and twisted in a most remarkable manner. At the corner near Messrs. Horsley's establishment, where the handsome electric lamp was swept away, a large number of street traders had as usual assembled for the Saturday night trade, and before anything could be done to save the stock, the entire "market" was hurled pell-mell into space, a most extraordinary mixture of merchandise whirling like an avalanche in the direction of the Green. Here a Royal Mail cart met the full force of the wind and was overturned, and several hansoms on the adjoining rank shared the same fate. To add to the confusion, some of the omnibus horses waiting on the hill adjoining the cab-rank stampeded for the stables, no doubt finding it too draughty for comfort out-of-doors, and several narrow escapes of pedestrians took place before the frightened animals were controlled. The tram-horses were also much startled by the noise and wind, but were prevented from bolting; and even a full-blown cyclone cannot do much harm to a tram-car. Curiously enough, the storm appeared to expend its fury on certain buildings, leaving their neighbours unscathed; and adjoining Camberwell Green itself there were visible evidences of this. For instance, the wind took a special fancy to the huge signboard placed at the top of the premises occupied by Messrs. Dunn, undertakers, and this was swept completely over the building, carrying part of the roof with it. Then, again, some three or four doors away (the intermediate buildings being apparently unharmed) a good slice of roof was taken off a house occupied by a greengrocer. At the corner of Camberwell Green, where there is a scaffolding enclosing the piece of land on which the police station formerly stood, a considerable portion of the upper part was swept away, and the builder's storebox was hurled from the staging.

The offices of the London Tramways Company in Camberwell New Road sustained considerable damage, hundreds of slates and part of a huge chimney-stack being carried into the middle of the road. The Surrey Masonic Hall, where a concert was proceeding at the time, did not escape the fury of the storm, which detached several pieces of masonry from the roof; but the greatest damage was that which befell the Station Hotel, immediately opposite the Chatham and Dover Station. Here the wind completely wrecked a large conservatory in the rear of the building, and not only tore away the inner doors, but dragged the lintels from the walls. In the buffet a scene of the utmost confusion occurred. Large flower-vases, glasses, decanters, and ornaments were swept from the counter, while a shower of bricks and slates fell through a broad skylight, part of the débris slightly cutting a female customer's neck. Something like a panic ensued, many of the customers rushing *en masse* into the private part of the house. The proprietor of the hotel, Mr. C. H. Sisman, who displayed considerable presence of mind, allayed the fears of his customers. The roof was almost completely lifted from the building, and the bedrooms rendered unfit for habitation.

At the Athenæum the whole of the lights in the bars were extinguished, and the well-known proprietor of the oyster and whelk stall outside the premises was horrified to find the whole of his stock-in-trade and appliances demolished by the fierce blast, and was only partially consoled by an immediate "whip-round" of Mr. Martin's customers for a subscription to indemnify his loss.

The Catholic Apostolic Church, in the Camberwell New Road, escaped almost entirely, with the single exception that some lead-work on one of the porches was twisted into singularly fantastic shapes. The ground in front of the Church of the Sacred Heart, adjoining the railway, was full of uprooted trees, one gigantic specimen lying across the doorway, forming with its main bough a species of natural archway, and one of the lamps over the gates was bent over at a right angle, but, curiously enough, no damage whatever was done to the two notice-boards standing close to the roadway on either side of the entrance. A few yards further on some serious damage was done to the Congregational Church. A good many slates were displaced from the roof, while an ornamental stone pinnacle, weighing a hundredweight, over one of the entrance doors was snapped completely off; the ornamental metal-work on the roof was cut clean off, and other damage was done, though, singularly enough, mostly on the side of the church remote from Camberwell Green. At other points in Camberwell New Road were to be seen traces of damage, in the shape of broken roofs and windows; and in the rear of the houses adjoining the hotel broken chimney-pots, bricks, slates, and cistern-tops were piled in the yards in extraordinary quantities.

Some of the most extraordinary damage was, however, that done in Baldwin Crescent, where the final energy of the storm was exercised. In sweeping round the corner the wind completely carried away the brickwork over the dormer windows on the roofs of three houses,—two on one side of the road, and the other immediately opposite,—while precisely similar damage was observed in the case of a house about half-way up the road, and another residence immediately opposite to this sustained some injury to the roof. These were the only instances of damage in this road, and throw curious light on the partial manner in which the cyclone distributed its unwelcome favours.

Fortunately, the catastrophe was not attended by any serious personal injury, although some of the falling slates and bricks caused one or two slight accidents. The heavy rain drove every one to the nearest shelter, and while the main outburst of the storm lasted the pavements were practically deserted. At a moderate computation, the general damage to property, etc., in the immediate vicinity of the Green will amount to many thousands of pounds.

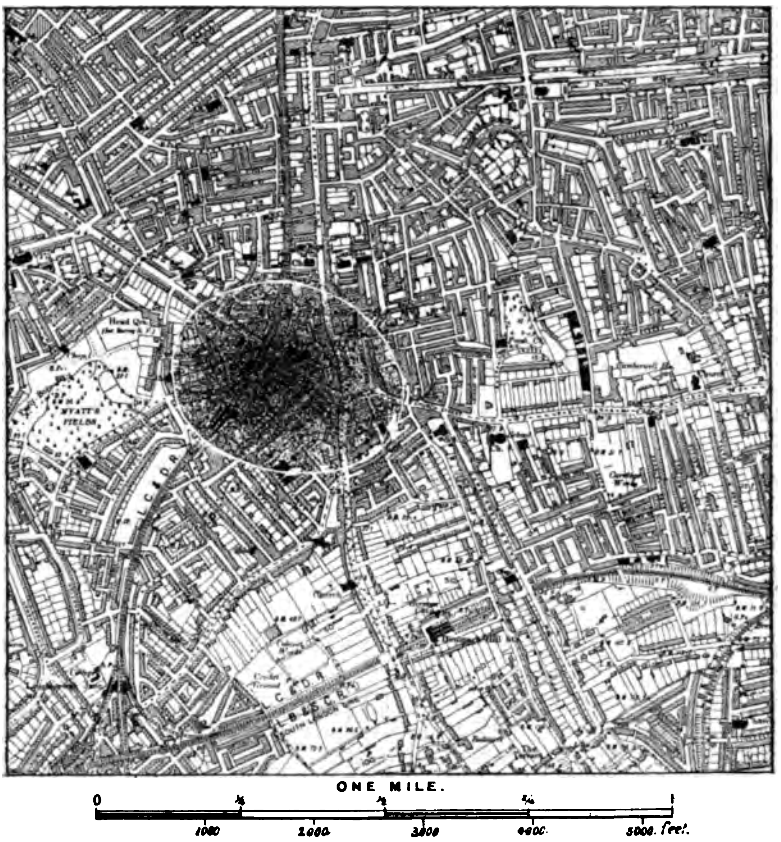
I went to Camberwell on October 31, accompanied by Mr. Phillpott, and walked through the whole of the district. We found that the above account fairly described the damage that had been done. The area affected was about half a mile in width and half a mile in length.

From the direction in which the trees were lying at Camberwell Green and in the piece of ground in front of the Church of the Sacred Heart, as well as from the damage to chimney-stacks, etc., it appears that the blast must have come from the North-east. The time of the occurrence was about 9.20 p.m., and the duration only two or three minutes.

The weather chart at 6 p.m., October 29, shows that there was at that time a small secondary disturbance over the south-east of England. Thunderstorms occurred at many places in the same district between 7 and 9.30 p.m., and later on in the Eastern Counties.

The barometric records show considerable oscillations in the mercury between 9 and 10.30 p.m. Very heavy rain fell between 9 and 10 p.m.:

the amount at Greenwich during that time was 0·77 in. The wind suddenly shifted at Greenwich at 9.20 p.m. from East-south-east to South-west, without any increase in force. At Kew the wind, although very light (the velocity being only about 5 miles per hour), shifted at 9.10 p.m. from South-east to South-by-east. The pressure-tube recording anemometer on the Tower Bridge showed a sudden increase of wind at

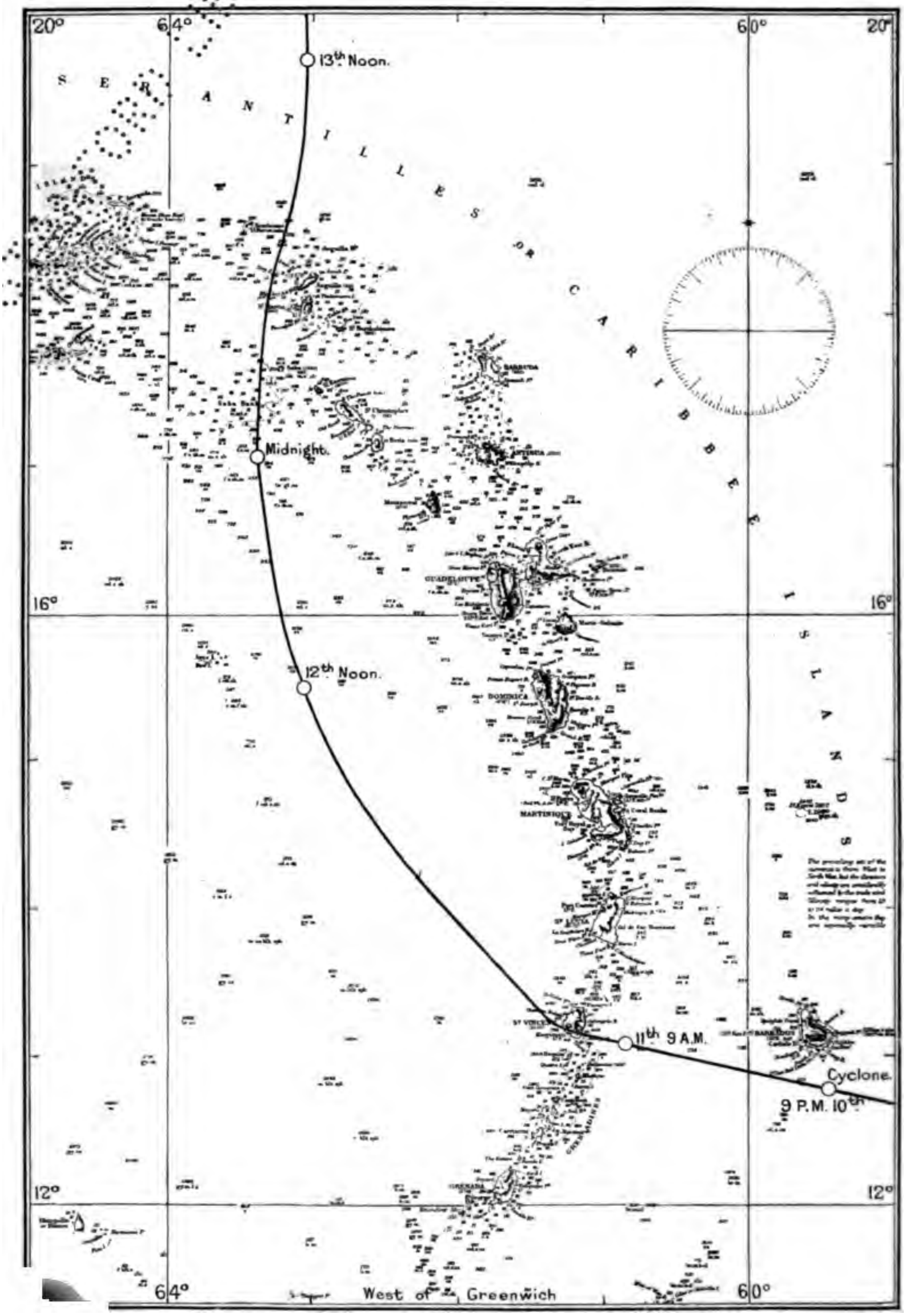


Map of Camberwell and neighbourhood.
The area of the structural damage is enclosed by the white line.

9.25 p.m., the pressure rising to 2·1 lbs. on the square foot, and then as quickly falling off again.

At Wallington, Mr. Bayard's barographic trace shows a sudden fall at 9.7 p.m. of ·04 in. and then a sudden rise of ·03 in., the whole occurrence lasting less than five minutes. No doubt this was part of the tornado formation. Unfortunately, I have not been able to obtain any barometric or anemometric records from the immediate neighbourhood of Camberwell, so cannot say what were the conditions which prevailed during the passage of the tornado. It is probable that the tornado was formed between two of the thunderstorm disturbances previously referred to.

CHART OF THE WINDWARD OR CARIBBEE ISLANDS SHOWING THE TRACK OF THE HURRICANE SEPTEMBER 10TH–13TH, 1898.



From Admiralty Chart.

DISCUSSION.

Mr. C. Harding remarked on the absence of damage at Camberwell Railway Station, where some extensive building operations were being carried out, and which, being so near to the scene of the damage, might have been supposed to have offered a minimum of resistance to the wind. With reference to the damage in Baldwin Crescent, he had it on the authority of a builder of repute in the neighbourhood that the windows were not blown outwards, but the damage was due to the wind striking the cornices behind. He was of opinion that the damage was done by a South-east wind, and not by one from the North-east, as stated by Mr. Marriott.

Mr. G. J. Symons considered that in storms of this type damage was quite as often due to the expansion of air within buildings as to direct wind-force.

Mr. W. Marriott said he did not agree with Mr. Harding that the damage was done by a South-east wind, as the fallen trees and chimney-stacks indicated that it was caused by a North-east wind.

THE WEST INDIAN HURRICANE, SEPTEMBER 1898.

By Capt. A. CARPENTER, R.N., D.S.O., F.R.Met.Soc.

(Plate II.)

[Read December 21, 1898.]

In bringing this paper before the Society I must state at once that it will not deal with the science of hurricanes in general, but will be a simple report on the course and devastation of a very fierce cyclone which swept over the islands of Barbados and St. Vincent in September last.

The information at my disposal has been very small, and includes only one reliable register of weather from a vessel within the sphere of influence. I have received from the Meteorological Office all the information which has reached it, and have to express my thanks for this. Some vessels which might have given valuable information were destroyed. Unfortunately, too, for such research, the meteorological stations on shore are at the chief ports of the islands, which lie on the lee side of very high land. A true estimate of the direction of wind in the open cannot thus be obtained, nor can observations of the swell from the eastward be made.

In the month of September the high-pressure area which occupies the whole of the North Atlantic, having its centre south-west of the Azores, usually throws out ridges toward both Spain and the United States, and the isobar of 30·0 ins. sweeps in a curve from Cape Verd Islands to Barbados, whilst a low barometer lies far away north over Greenland. The winds of the North Atlantic sweep round this area of high pressure, forming a vast anticyclone, with winds of an average force of 4 to 5 on the Beaufort scale.

The heat is considerable in the West Indies in September, and the isotherm of 80° embraces the whole of the islands and just touches Bermuda.

Cyclonic storms or depressions are not uncommon north of the 35th parallel. They commence either overland or close off the coast of the

United States, and travel towards Europe and Spitzbergen at rates varying from 200 to 800 miles a day, apparently borne along by the prevailing winds. The force of wind in these storms frequently attains to destructive violence, as indeed we realise when our coasts are strewn with wrecks, but it does not appear to reach the almost malignant strength that is common to the cyclone found between the tropics.

The months of August, September, and October, it is well known, are those in which cyclones are most likely to occur in the West Indies south of lat. 25° N.; and it is found that, on an average, about two occur in each of those months. In the year 1889, however, no less than six occurred in September.

There is no particular place of origin, except that they commence over the open sea, and always north of lat. 12° N. Such as originate south of lat. 22° N. appear to pursue a westerly path at first, while those having their origin north of lat. 22° N. move off in a north-north-east direction. Those of more southern origin, as a rule, recurve to the north-east and eastward on attaining a lat. of 35° N.; but of course there are many curious exceptions, and one can only generalise.

The famous hurricane of August 1873 had its origin on the 15th parallel, half-way between Cape Verd and the Windward Islands, and it was traced for 3500 miles, recurving in lat. 35° N.

The St. Vincent cyclone under review proved no exception to the rule; and, as regards its path, was a well-behaved, orderly hurricane.

The U.S. Weather Bureau has established meteorological stations on many islands in the West Indies and at many places on their own coast, and the U.S. Hydrographic Office has consequently such a large amount of material on which to publish the monthly *Pilot Charts* of the North Atlantic Ocean, that I think we may safely allow the track of this storm set out on their issue of November 1st to be the correct one. Anyhow, it is likely to be more correct than anything that I could give. The observations taken on board H.M.S. *Alert* near Barbados, and those taken at St. Vincent and at Grenada, confirm the correctness of the first part of the path; but I have found it necessary to alter the position of the cyclone at noon on the 13th, the observations at St. Kitt's, Montserrat, and Antigua placing the centre 90 miles farther north than that given on the *Pilot Chart*.

I cannot say in what longitude the cyclone first made itself felt, but at Barbados, on September 6th, the weather, which had been the normal fine weather with gentle North-east and East winds, began to have a threatening appearance. The wind and lower clouds were from North-east, but the cirrus was moving up from South-east, and there were passing showers all day.

On the 7th the barometer was falling slightly, ·04 in. all over the West Indies, except at Barbados, where it was steady. There the weather had an unpleasant feeling, several thunderstorms occurred, and light rain fell on and off all day. There was also a tendency for the wind to get to the Northward. At Grenada the weather was wet and cloudy.

On the 8th, at Barbados and Grenada, the barometer rose ·02 in. At the first place the weather was again threatening, there were heavy showers, and it was very muggy. About noon half an inch of rain fell

in half an hour. In the early morning the cirrus clouds were seen to be moving from south-west. Fine rain had begun at Antigua.

On the 9th, at Barbados, there was a suspicious fall of the barometer in the afternoon, but it rose again slightly at 10 p.m. In other parts of the West Indies it rose slightly, except at Grenada, where it began to fall, and showed 29·95 ins. at 9 a.m. Gentle East-north-east winds prevailed at Barbados, with warm, cloudy, showery weather. There was a solar halo at 4 p.m. Heavy rain fell at Grenada, and light rain at Antigua.

On the 10th, at Barbados, the morning broke with a drizzle. Cirrus clouds were coming rapidly from the south. Weather very threatening. A heavy swell reported from the south-east. At 10 a.m. wind North-east, force 2. At 4 p.m. North-north-east, 2 to 5. At 6 p.m. the wind increased, and at 6.30 p.m. broke into a gale from North-east, and continued to increase. At 10.18 p.m. the anemometer and wind vane were blown down, and the rain gauge upset. After this the directions of the wind were not taken by night, but only by day, so that one loses valuable information as to direction. The rainfall was taken with an ordinary rain gauge instead of the tipping bucket.

The observer for the U.S. Weather Bureau, at Bridgetown, reports :—

Although the anemometer record sheet shows that the wind increased steadily in force, yet throughout the storm there were terrific instantaneous gusts, the velocities of which must have been very great. It was one of these that blew the instruments down. The greatest velocity recorded for five minutes, shortly before the upset, was 62 miles per hour, and the greatest for one minute 75 miles per hour. Between 10.18 and midnight it was much greater than at any time previous, and probably attained 90 to 100 miles per hour. It abated considerably after midnight.

No direction is given after the instruments fell. But probably the wind came from East and South-east. No central lull or calm was reported, so Bridgetown was probably just outside its inner circle.

The rain had begun steadily at 1.15 p.m., and continued until next forenoon. 5½ ins. fell between 6 p.m. of 10th and 6 a.m. of 11th, and altogether 11·42 ins. from 6 p.m. of 10th till 10.30 a.m. of 12th, that is, in 40½ hours. The average annual rainfall is about 58 ins.

The barometer, corrected, which showed ·04 in. lower at 4 a.m. on the 10th than it had at the same hour on the previous day, now only rose ·03 in. by 10 a.m., the usual semi-diurnal rise being ·06 in. At 11 a.m. it stood at 29·91 ins., and from then commenced to fall steadily till 6 p.m., after which it fell rapidly till 9.20 p.m., when it reached its lowest point, 29·462 ins. The subsequent rise was fairly uniform.

H.M.S. *Alert*, a sloop of 960 tons, was anchored in Carlisle Bay off Bridgetown, Barbados, on the 10th, and, being alarmed at the threatening appearance, got up steam and put to sea at 6 p.m., running to the southward at 10 knots, and crossing the path of the coming cyclone. On clearing the harbour she found that the wind was North, force 4 to 6, squalls of heavy rain and much lightning, but no thunder. At 9 p.m. she had crossed the front of the storm, and had North-north-west wind, force 6 to 9, the glass falling to 29·60 ins. The storm centre appears to have been then distant about 25 miles in an east by north direction.

The sea was very heavy from the north, and the ship rolled heavily, the pendulum of the inclinometer striking both sides of the case. She took in several seas over the starboard netting. At 10 p.m. the wind shifted, in a heavy squall, to West; and at 11 p.m. to West by South. The barometer commenced to rise again at 11.30 p.m. There was a heavy following swell. At 5.30 a.m., being then near Tobago, the *Alert* altered course to south-west for Trinidad, the swell still following her, and the wind then right ahead. At 10 a.m. the barometer had risen to 29·88 ins. corrected, and at 5 p.m. had dropped again a tenth. With the wind still at South-west, but very light, she anchored at 7 p.m. off Port of Spain, Trinidad. At that place there had been very threatening weather, and a heavy swell all day. During the night some new disturbance occurred, for they had sharp squalls from East-south-east to South-east, with very heavy rain, lightning, and thunder. This lasted till noon on the 12th, when the wind shifted back to South-west, and died away slowly.

Returning to Barbados, we find that the heavy squalls between 9 and 10 p.m. on the 10th had caused most of the shipping at Carlisle Bay to drag their anchors out to sea. Five vessels—one of 1500 and two of 600 tons, a schooner, and a coal hulk—were blown to sea in company, dragging anchors and cables with them. By 10 p.m. they had lost all masts and spars, and were drifting helplessly, broadside on, at about 7 knots per hour, over the ground, *i.e.* over the sea bottom. The rain fell in torrents, incessant lightning played round them, in the flashes of which they caught glimpses of one another, and the spray went over the vessels in blinding sheets. At 6 a.m. they found themselves in the centre of the cyclone, and it fell calm for nearly half an hour. They saw each other clearly for the first time. Then the wind shifted to the South for an hour, and this blew them back into the north-east quadrant of the storm, where a fierce East-north-east wind nearly finished them off.

Finally, three of them were mercifully thrown ashore on the sandy coast near Georgetown, on the east side of St. Vincent. It was then noon, and they had drifted some 105 miles in 15 hours. The coal hulk, I believe, went on the rocks somewhat south of the others, and the schooner was not heard of again. At noon the central calm was passing over Kingstown.

On the morning of the 11th, at Barbados, the wind was South-east at 9 a.m., and South at 3 p.m.

At *St. Vincent*, on the 10th, the fall of the barometer to 29·84 ins. at 3 p.m. gave warning at Kingstown that some disturbance was imminent, and notices were sent to various parts of the island. In the afternoon there was a strange noise in the air, which proved later to be the roar of the surf on the weather coast. People felt restless and uncomfortable. By 6 a.m. on the 11th the wind was blowing in sharp, fitful gusts from North to North-west, and the glass was down to 29·724 ins. At 9 a.m. the wind was rushing about from North to West, the varying direction being possibly accounted for by the high land, ridges of 2000 ft., to the north of the town, and the barometer was down to 29·606 ins., and it became very dark. The centre of the cyclone was then distant about 21 miles. At 11 a.m. the wind was North-west to West, the barometer 28·90 ins., and buildings and trees were being

blown down in all directions. I have not been able to get any anemometer observations from this island.

At 11.40 there was a lull almost to a calm for three-quarters of an hour. About 12.25 the wind recommenced from due South and increased every minute, after which every exposed house and tree that had previously escaped was blown down or damaged. During the lull the barometer remained steady at 28·51 ins. At 2.30 p.m. the wind slackened considerably.

The rain had fallen heavily on the 10th, but I have no record how much fell in the night. It must have fallen very heavily in the forenoon of the 11th, for the gauge registered 4·94 ins. between 9 a.m. and noon.

Mr. Powell, the Curator of the Botanic Gardens, on whose report I chiefly rely for my information, considers that the same quantity fell again between noon and 3 p.m., but the gauge was knocked over by a falling tree and the record lost. From 3 p.m. on the 11th until 9 a.m. on the 12th, 4·23 ins. fell. Thus the recorded rainfall in the 24 hours was 9·17 ins., and the probable total fall 14 ins. The average annual rainfall is 80 ins. The following rapid fall of the barometer is interesting:—

A.M.	Ins.	A.M.	Ins.
10.0	29·539	11.20	28·719
10.30	29·409	11.25	28·669
10.55	29·119	11.35	28·519
11.10	28·819	11.40	28·509

A fall of 1·03 in. in 1 hr. 40 min. gives a gradient of ·088 in. per mile, the cyclone at that time travelling about 7 miles an hour. This is very steep.

At *Grenada*, distant 75 miles to the south, the barometer fell nearly a tenth between the 10th and 11th, and there was considerable thunder and lightning all night. 2¼ ins. of rain fell between the 9 a.m. observations of both days, but then ceased. A brisk Westerly wind took the place of the usual East wind on the morning of the 11th. On the afternoon of the 12th the mountains of Trinidad Island, 3100 feet high, were visible from Grenada, distant 90 miles, a very rare occurrence.

At *St. Lucia*, the heavy rollers entering Castries Harbour and the threatening appearance of the sky at 3 p.m. on the 10th gave indication of the approaching cyclone, which was then distant 155 miles. The barometer fell regularly after 9 a.m. of the 10th, and reached its lowest at 4 p.m. on the 11th. After 10 a.m. on 11th the East wind increased rapidly to force 11. Temperature, 78°. At 8 p.m. the rain came down very heavily, and fell in torrents throughout the night, overflowing the rain gauges. It was estimated that 20 ins. of rain fell. The chief damage to the island was done by rain. The barometer stood at much the same height from 10.30 a.m. till 6 p.m. Lowest recorded, uncorrected, 29·71 ins.

At *Dominica Island* there was continuous rain on the 9th and 10th, and very heavy rain on night of 11th. 5½ ins. fell between 9 a.m. of 11th and 9 a.m. of 12th. Temperature, 75° on 10th and on 12th, which is 10° below normal. Lowest recorded barometer, 29·82 ins. at 3 p.m. on 11th; probably it fell lower during the night.

At *Montserrat Island*, in lat. 16° 45′ N., on the 10th and 11th, the winds were North-east, gusty. On the 12th, at 7.50 a.m., it was blowing a gale, force 9, from East by North. It continued from East all day until 9 p.m., but was from South at midnight. One would have expected the wind to veer after noon on the 12th, but it seems probable, from irregularities observed at St. Lucia, Dominica, and St. Kitt's, as well as at this island, that there was a subsidiary depression travelling on the right side of the cyclone. From 9 p.m. till midnight the force of the wind was 10. The rainfall was 17¼ ins. in 48 hours, 12¼ ins. of this falling between 6 p.m. of 12th and 7 a.m. of 13th. The temperature fell to 70°, which is very cold. Lowest barometer was at 6 p.m. on 12th.

At *St. Christopher Island*, or, more commonly, *St. Kitt's*, the wind had increased from the usual Trade Wind to force 6 on the 11th, and the direction veered regularly as the cyclone worked to the northward. At midnight on the 12th the centre bore about West-south-west 42 miles, and the barometer, uncorrected, showed 29·80 ins. The temperature fell 6°. Their strongest blow was from South-west. The rainfall from morning of 12th till morning of 13th was 5½ ins.; and the same amount fell at the neighbouring island, *Antigua*, from morning of 11th to morning of 12th. Twenty inches fell at *Nevis* during the gale.

At *Jamaica*, the barometer fell slowly ·13 in. between the 9th and 15th. On the 10th and 11th considerable rain fell, and the general temperature fell 12° with it.

We will now follow the path of the cyclonic centre and note a few points. The cyclone, passing 18 miles south of Barbados, swept over the southern half of St. Vincent Island, then took a north-west direction towards Aves Island, its rate of progression being about 7½ miles an hour. From here it pursued a northerly course for 450 miles, passing between Puerto Rico and the Windward Islands. In lat. 23° N. it swerved to the north-west for 600 miles up to lat. 30° N., where, on the 17th, it commenced to recurve to the north-east. It was traced to lat. 44° N., long. 42° W., where it was still going strong on the 20th, having travelled 3000 miles at an average speed before recurvature of 8 miles an hour, and of 24 miles an hour afterwards. The incurvature of wind was greater in the left and rear than in the right and front quadrants. This is usually so in West Indian hurricanes.

Its diameter (taken as the limit within which there was a marked change in direction of wind) was 80 miles as it approached Barbados, and 170 miles after leaving St. Vincent. The actual storm centre, in which the force of wind greatly increased, was only 35 miles in diameter until St. Vincent was passed, but after that the strength of wind extended to 170 miles from its centre. The diameter of the calm vortex, or eye, of the storm was not less than 4 miles. Contact with the high land of St. Vincent probably caused the cyclone to deviate.

On nearing Bermuda the diameter of the cyclone was about 400 miles, and on passing Nova Scotia 450 miles, as depicted on the *U.S. Pilot Chart* for November.

The damage to the islands was necessarily very great, the crops and vegetation not being inured to heavy storms.

The houses of the peasantry are all of wood, and those of Europeans are built of stone or brick only in their lower courses.

In Barbados 11,400 houses were swept away or blown down. Some of these fell outward from all sides as if by an explosion from the interior. About 115 lives were lost, and 50,000 people became homeless.

At St. Vincent 6000 houses were blown down or damaged beyond repair, 200 lives lost, and 20,000 people homeless. Not only were wooden houses blown down, but also nearly all the churches and chapels were destroyed. Trees nearly a century old were uprooted, and the rain filled the mountain torrents to such magnitude that whole villages were swept away and estates wiped out beyond recognition. The high sea damaged Kingstown, and all shipping was destroyed. The whole island was blasted as by fire.

At *St. Lucia*, the rain converted valleys into lakes, and an avalanche filled a valley for 3 miles, burying houses and estates. The high sea did much damage at Castries Harbour.

The same tale is told farther north, the heavy rain doing even more harm than the wind. The finances of these islands were already in an impoverished condition owing to the sugar question, and this wholesale destruction has caused much misery. A subscription for the relief of the sufferers was opened at the Mansion House, and £44,000 was realised by the middle of November, but this is unfortunately quite inadequate.

It does not appear that any of the meteorological observers have made arrangements for receiving reports of the height and direction of the ocean swell from the weather coasts during the hurricane months. I feel sure that they lose a very valuable warning by not doing so.

In August 1880, at Port Royal, Jamaica, I received nearly twenty-four hours' notice of the cyclone that swept over the island, wrecking every vessel except the Commodore's ship and my little surveying schooner. None of the local folk saw anything unusual in the look of the weather, but the sea outside on the reefs was out of all proportion to that due to the ordinary sea breeze.

The surf was roaring on the east coast of St. Vincent twenty hours before the cyclonic centre reached it, and at St. Lucia, where the cyclone was 155 miles distant.

There was much atmospheric electricity over all the islands from the 10th to the 14th, their reports all speaking of a remarkable electric display.

At Barbados such a display occurred over the entire heavens, and a few people felt a slight shock of earthquake. On the night of the 10th a brilliant permanent light appeared to the south-west. No explanation of this is offered. It must have been considerable, for the distant view would have been obscured by the heavy rain.

The three vessels blown from Barbados to St. Vincent report incessant lightning. The crews of these ships were saved, and proceeded overland to Kingstown. They stated that the whole island looked "as if a fire had passed over it, the leaves not so much withered as parched up, and the trunks blackened. Any one landing on the island would exclaim, 'What an awful fire must have taken place here!' The bread-fruit had the appearance of being cooked."

The following extracts from a lady's letter speak volumes. She lived in a well-built house in Fort Charlotte, overlooking Kingstown, and has written a very clear account:—

"I thought I felt an earthquake about 7 a.m. on the 11th. It was very wild looking, sea very rough, and the wind blew the spray about like water-spouts." Then she details the fight with the shutters, the roar of the sea, the crash of falling trees, and the unroofing of her house. She writes: "The rain was scalding hot, and poured down through the open roof. It was pitch dark outside, except for a strange sort of fire (not flashes of lightning) all over the sea and ground." This was before the lull in the forenoon. During the lull they came up from the cellar, and the interior of the house was "as if a fire-hose and mad bulls had been let loose in it." "The sea was like a boiling cauldron—all our trees and our stables gone." The afternoon was, if anything, worse. "The smell next morning was something awful. Goodness knows what fell on this land from the sky that day." "It was not ordinary rain: the water was boiling, and smelt putrid. All the clothes that got wet rotted after being washed. The grass was burnt as by fire."

On another part of the island a planter's family, crouching under a wall behind their house, saw their piano whiz over their heads and stick on top of the bakehouse. They ran into the open, and they report that "smoke and flames were around them, and boiling water fell on them."

The captain of H.M.S. *Intrepid*, who was sent from Halifax with stores, makes the same remark as to the appearance of the island having been burnt with fire.

This is sufficient to show that there was something unusually electrical about this storm. Whether the earth opened beneath the sea and shot forth sulphurous steam which afterwards descended as hot rain, there is no evidence to show. The volcano Soufrière, at the north end of the island, has been dormant since 1812. A lake, half a mile in diameter, lies in the crater. It seems possible that this water, which under a tropical sun must bear a high temperature and be somewhat foul, may have been licked up by the cyclonic whirl, and descended as stinking rain, the high temperature, perhaps 90°, contrasting with the ordinary cold rain. The island is only 17 miles long.

NOTE.—The meteorological observations at Sombrero Island, received since the above was written, show that the cyclone passed close to the east of that island at 3 a.m. on the 13th. Its position at noon on that day has therefore been placed still farther north, in about lat. 19° 40′ N. It is noteworthy that the swell began to surge against Sombrero Island on the 7th, and increased on the 8th and 9th, becoming *high* on the 10th, and *heavy* on the 12th. On the 7th the cyclone could not have been less than 800 miles distant.

DISCUSSION.

The President (Mr. F. CAMPBELL BAYARD) said that Capt. Carpenter had undertaken this inquiry at the desire of the Council, and their thanks were due to him for the labour he had expended in the collection and collation of the information relating to this most disastrous hurricane. With regard to the excessive rainfall, there did not appear to be any satisfactory measurement made anywhere under the influence of the storm, the gauges having been either blown or washed away. It was unsatisfactory to find that in the islands most affected, though all under British rule, there did not seem to be a single self-recording rain-gauge, which would to some extent have obviated the difficulty.

Mr. G. J. Symons said that he was not responsible for rainfall observations in the West Indies, but he had no doubt that the observers there had developed the characteristic of all rainfall observers, viz. a state of unpreparedness for anything abnormal. He had been preaching for years, but he was afraid a great many observers in this country were proportionately as unprepared for a fall of 4 inches, as the West Indian or other tropical observers were for falls of 10 to 20 inches. With reference to the successful forecasting of these storms, perhaps Dr. Scott might give some information. The American Weather Bureau had already taken advantage of the opportunity of establishing stations in the West Indies, an opportunity afforded not so much by right of occupation as by that international courtesy which was such a happy characteristic in scientists all the world over. The U.S. Weather Bureau, which was under the control of the Department of Agriculture, was a very progressive body, and before the war in Cuba was brought to a close, arrangements had been made for sending from there to the headquarters at Washington such information as would be deemed of importance to mariners and others on these coasts. Subsequently they had nominated one of their most capable men as director of their stations in Cuba, so that there was every prospect of the next hurricane being thoroughly observed. Unfortunately, till now there had been a peculiar lack of organisation respecting these storms. Sir Rawson Rawson had gathered some data out there, but he (Mr. Symons) did not think that there was much, if any, inter-colonial correspondence on these matters between the islands; so it was gratifying to find that some one had taken the investigation of the matter in hand, and he thought the Weather Bureau at Washington well qualified for that purpose. It was a rich body, having a grant from the Senate of about $250,000. The late British Consul at Santiago had interested himself in the forecasting of these disturbances. The West Indian Islands were now almost all connected by submarine cable; and he thought it only reasonable to expect serviceable information through this agency.

Dr. R. H. Scott remarked that the American Weather Bureau had for 12 or 14 years been gradually establishing stations in more than one of the West Indian Islands, and he (Dr. Scott) regarded any money as well spent which furnished such valuable information as was obtained. In his opinion, the origin of these disturbances was not in Cuba or its vicinity, but rather nearer Barbados, or the Windward Islands. He agreed as to the lack of reliable data from the British West Indies, but when the islands were in an impoverished condition, as many were, through the high sugar bounties and other causes, it was scarcely reasonable to expect meteorological research to flourish. In 1879 Sir Henry Lefroy proposed through the Meteorological Council to the Colonial Office to establish a station at Antigua, but the scheme was not carried through. The only observer at Trinidad was Mr. Hart, the head of the Botanic Gardens; and the other islands, with the single exception of Jamaica, were as badly off. He thought great credit was due to Capt. Carpenter for his admirable account of the hurricane, given as it was at such short notice. He would further remark that he had heard from Sir J. Goldney, who had visited St. Vincent since the date of the cyclone, that the heated rain had been mentioned by several residents.

Mr. C. Harding said that, while agreeing with other speakers as to the creditable way Capt. Carpenter had dealt with the material collected, he (Mr. Harding) should have liked to see the storm traced from its origin to the time it dispersed. It was noted in the paper as first appearing 18 miles south of Barbados, but its intensity was then well developed and nothing could be learned of its origin. To successfully trace the birth of this disturbance, it was necessary to get a great number of marine observations, which, he was aware, was of some difficulty. From an examination of the Daily Weather

Charts there seemed to be indications of this disturbance striking the south of Europe, there being evidence of depressions in that neighbourhood, about the time it would be expected to arrive there had it followed a course in that direction after being lost sight of in mid-ocean. He thought Capt. Carpenter perfectly justified in calculating the centre of the storm at noon 13th to be to the north of the track marked on the *U.S. Pilot Chart*, and data that had been received subsequently, which he (Mr. Harding) had access to, confirmed the alteration; and he (Mr. Harding) would make the position of the centre at mid-day 13th even 100 miles farther north than now given by Capt. Carpenter—the centre being approximately in 19° 30′ N. latitude. At Sombrero on the 13th, at 3 a.m., the wind was North-north-west, force 12, and the barometer 29·48 ins. (the observer remarked that he had never seen the barometer fall so rapidly in his life), these observations showing that the centre of the storm passed close to the island.

Mr. R. Inwards thought that the statement regarding the phenomena of scalding rain should be confirmed. Probably the temperature of the rain was unusually high, and this had been exaggerated to "boiling hot." With reference to the emptying of the volcanic lake by the spiral whirl, he thought further evidence could be afforded by travellers, or others now resident on the island.

Capt. A. Carpenter said that he regretted he had not traced the storm from its origin, but the want of material and time placed him at a disadvantage. There was no doubt that the hurricane was well developed when it appeared off Barbados, and was still going strongly when last observed in long. 42° W. He was glad to be confirmed as to the position of the storm centre at noon on the 13th by the observations at Sombrero Island to which Mr. Harding referred. He was disappointed that no official had made observations as to the temperature of the rain, but only those persons whose houses were wrecked would be exposed to it and become aware of its phenomenal warmth. On the west coast of St. Vincent most of the villages were swept away, and the lady correspondent he had quoted supplied the only available information; this being the side where, in all probability (had the water from the volcanic lake been drawn up), the deposit would have been. In conclusion, he had to express his best thanks to Mr. Symons and to the Meteorological Council for information and access to charts and logs.

THE CONNECTION BETWEEN THE WINTER TEMPERATURE AND THE HEIGHT OF THE BAROMETER IN NORTH-WESTERN EUROPE.

By W. H. DINES, B.A., F.R.Met.Soc.

[Read December 21, 1898.]

In the spring of 1897 I read a paper before the Society dealing with the connection between frost and anticyclonic conditions at Greenwich. The period dealt with was 1841-90 inclusive, and the statistical evidence obtained left no doubt on my own mind that the current theory on the subject is radically false. In that paper it was shown that the mean height of the barometer during nearly all the noted frosts of the period was below the average, and that 16 frosts only out of 74 had been accompanied by a high barometer (above 30·20 ins.), and that, whereas

the average duration of a frost was 9 days,[1] the average of those 16 high barometer frosts was only 6 days.

These facts are to me quite conclusive, but in the following tables and diagrams I have treated the question from another side, and have also extended the results to Western Europe.

First, with regard to Greenwich. Any one who will take the trouble may obtain the following data.

During the three winter months (December, January, February) of the 50 years 1841-90 there were 416 days on which a barometer reading, corrected and reduced to sea-level, between 30·20 and 30·30 ins. was observed, and the mean temperature of these days was 38°·6. Between 30·30 and 30·40 ins., the number of days was 334, with a mean temperature of 38°·4.

Given as a table, the figures appear as follows :—

Barometer Reading between	Number of Days.	Mean Temperature.
ins. ins.		°
30·20 and 30·30	416	38·6
30·30 and 30·40	334	38·4
30·40 and 30·50	275	38·8
30·50 and 30·60	201	37·9
30·60 and 30·70	112	37·7
30·70 and 30·80	32	36·1
Above 30·80	6	36·8

This table deals with 1376 days, and out of these 211 were days on which the mean temperature was below 32°·0; this gives a percentage of 15. During the whole period there were 4463 days, and of these 662 had a mean temperature below 32°·0. By a curious coincidence this percentage is again 15. Taking the 38 days on which the barometer was above 30·70 ins., 4 only were days of frost, giving a percentage of 10·5, although the mean temperature of these days is decidedly below the average. The mean temperature of the 1376 days included in the above table comes out as 38°·3, thus closely approximating to the winter temperature at Greenwich.

Turning now to Western Europe, three stations were selected, from which fairly long returns are available, viz. Christiania, 26 years, 1868-93; Berlin, 46 years, 1848-93; and Geneva, 56 years, 1840-95. It has been considered sufficient to use the monthly means, and a little consideration will show that these are enough to prove or disprove the theory. For, suppose that the barometer were high during a certain month, if the rule be that cold weather accompanies a high barometer, such a month must in general have had a temperature below the average; for, the monthly mean of the barometer being above the average, the height on most of the days must have been so. Hence most of the days of such a month should have been cold, and the mean temperature of the month below the average. Similarly, a month with a mean below the usual barometric pressure should, if the rule be true, certainly have had a high temperature.

Hence, if the rule be true, we shall find those months in which the barometer was high on the whole colder than those in which the barometer was low; and if no such correspondence can be traced, provided that the

[1] In the former paper this figure was 13, but it is corrected to 9 in the Errata to vol. xxiii.

period considered be long enough to eliminate accidental anomalies, the theory must fall to the ground.

A connection of this kind is most readily seen on a diagram, and the nine accompanying curves (Figs. 1, 2, and 3) show the variation of the temperature for the month considered for each of the winter months at each of the three stations. The months are arranged with reference to the height of the barometer; the month with the highest barometer standing first on the left hand, the next highest second, and so on. This plan avoids drawing two curves, and also shows the connection, if any, more readily. The December curve for Berlin, for example, is constructed thus. Out of the 46 years that are available, the December

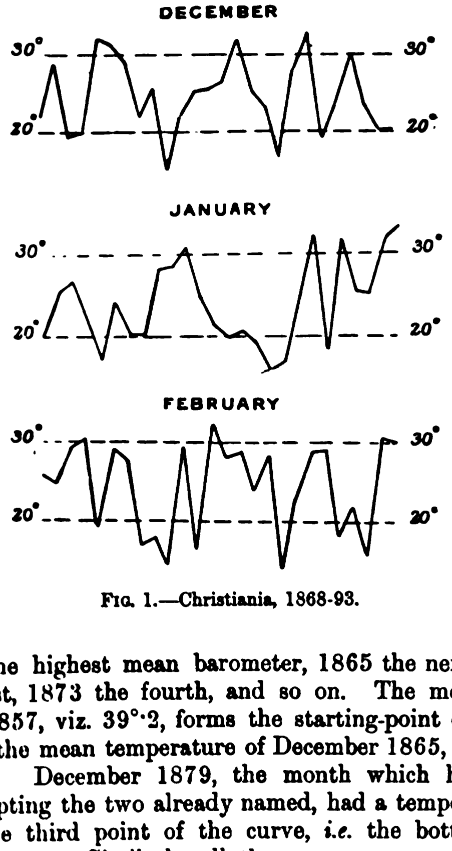


FIG. 1.—Christiania, 1868-93.

of 1857 had the highest mean barometer, 1865 the next highest, 1879 the third highest, 1873 the fourth, and so on. The mean temperature for December 1857, viz. 39°·2, forms the starting-point of the curve on the left hand; the mean temperature of December 1865, viz. 36°·6, forms the next point. December 1879, the month which had the highest barometer, excepting the two already named, had a temperature of 24°·1, which forms the third point of the curve, *i.e.* the bottom of the first sharp V, and so on. Similarly, all the curves are arranged so that the dates stand in descending order of the heights of the barometer. Going to the left hand at any point we come to a month of higher, and to the right to a month of lower, barometer. Hence the barometer curves, were they put in, would all slope steadily downwards from left to right, and were the theory true, the temperature curves shown on the diagrams should slope steadily upwards to the right. They do not so slope upwards. Some have a very trifling slope one way, and some the other;

but they are mostly level, and are just such curves as one would expect to obtain if the order of the months were arranged by chance instead of by reference to the height of the barometer. At Christiania the curves may be considered as practically level, at Berlin there is a slight tendency for the colder months to occur with the high barometer, but at Geneva this is reversed.

To show the form of curve we might expect if the supposed connection did exist, a temperature curve dealing with the same figures has been drawn, but in a different way.

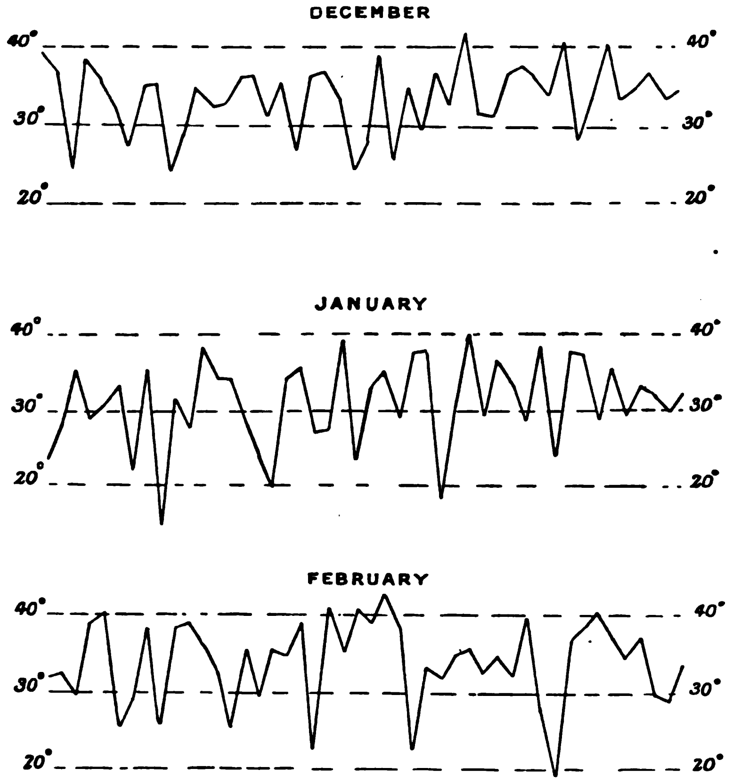


FIG. 2.—Berlin, 1848-93.

If the barometer be high at Berlin during a certain month, it is a natural inference that anticyclonic conditions prevailed over North Germany during that month, and it follows that there should be a greater prevalence than usual of Easterly winds over Switzerland, and this again should lower the temperature at Geneva. That this is a perfectly legitimate conclusion is shown in the three curves (Fig. 4, p. 37), in which the months are arranged with reference to the height of the barometer at Berlin, but the mean monthly temperatures which form the curves are those of Geneva. The upward slope to the right is evident in each case.

I have not the slightest doubt but that the height of the barometer in

the north of Scotland and the temperature at Greenwich would show a similar correspondence; but the theory against which I protest is quite different, namely, that an anticyclone situated over a certain region produces cold in that region itself.

To recapitulate, we have the following facts:—

1. Frosts at Greenwich are not usually accompanied by a high barometer. The mean during the 74 frosts dealt with in the preceding paper comes out at 29·905 ins., a value below the average.

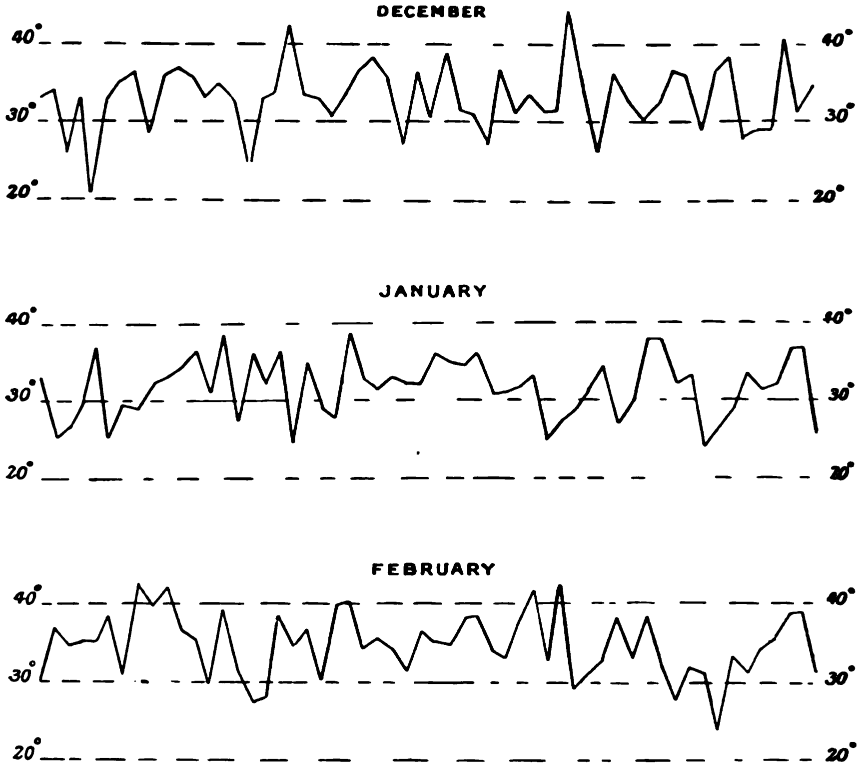


Fig. 3.—Geneva, 1840-95.

2. Severe or long-continued frosts at Greenwich have mostly been accompanied by a low barometer. The frosts of 1813-14 and of 1838 were no exceptions to this rule.

3. Days of high barometer at Greenwich have a mean temperature of 38°·4, which is much above the freezing point, and within 1° of the mean winter temperature; and the percentage of frosty days, neglecting decimals, is the same when the barometer is high as it is for the winter generally.

4. At the three representative stations in Western Europe—Christiania, Berlin, and Geneva—no connection can be traced between the height of the barometer and the temperature, although the height of the barometer at one station and the temperature at another, 600 miles to the south-west, are plainly connected.

Thus the three different ways in which the question has been investigated give the same answer, namely, that the winter temperature at a place in Western Europe has no connection with the height of the barometer at that place, and that in winter it is just as likely to be cold when the barometer is below the average as when it is above the average.

The question whether the term "anticyclonic" may be substituted in the above remarks for the term "high barometer" remains to be discussed. There is no doubt that a single observation of the barometer at one place affords no certain information as to the conditions of weather,

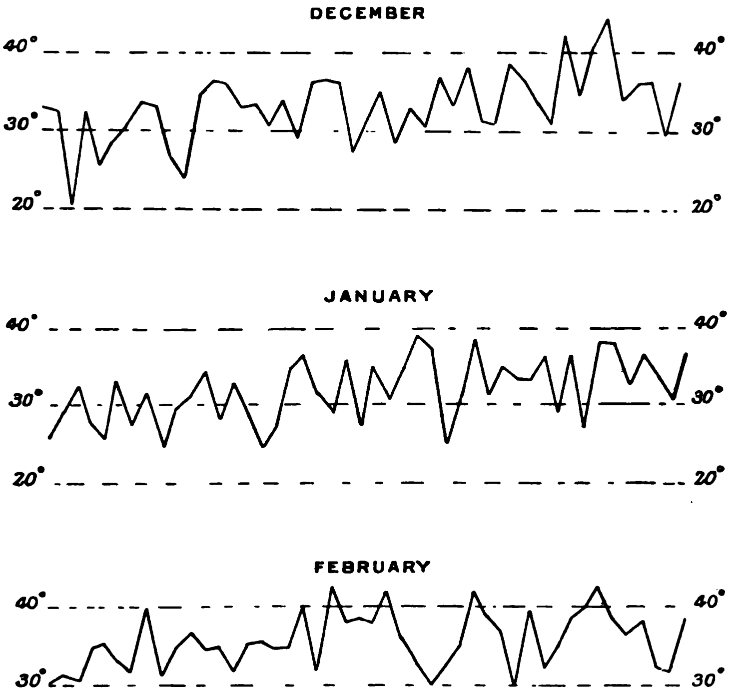


FIG. 4.—Barometer at Berlin, Temperature at Geneva.

anticyclonic or otherwise, at that place; but if the barometer be very high, the probability of the presence of an anticyclone is very great. If, instead of one day's observation, we have several days', and the mean of these days gives a high barometer, the probability that most of these days were anticyclonic is so great that it amounts almost to certainity; for no one will assert that cyclonic conditions are the usual accompaniments of a high barometer. I think Mr. Scott may be quoted as an authority for taking the conditions as anticyclonic when the barometer is above 30·20 ins. Taking the definition of an anticyclone given by Mr. Gaster in the discussion on my preceding paper, a study of the winter Weather Charts published by the Meteorological Office leads to the conclusion that the 30·0 ins. isobar generally divides the cyclonic from the anticyclonic region. At Greenwich, during the winter months, the prevalent

conditions of weather are cyclonic, and there is a probability of cyclonic conditions for a period when the barometer is at its mean value, much more therefore for a period when it is below its mean. Now the frosts of the years 1840-90 give a mean barometer of 29·905 ins., a value below the mean, and this being so, it seems to me impossible to believe that the conditions most favourable for a frost at Greenwich are anticyclonic conditions. Also, there is no special tendency for frost on days when the barometer is above 30·20 ins., days on which there is every probability of finding anticyclonic conditions. Again, looking at the curves for the continental stations, the months on the extreme left were remarkable for an exceptionally high barometer, and the probability is so great that it amounts almost to certainty that anticyclonic conditions prevailed during those months, yet they exhibit no marked tendency for cold any more than those on the right do for warmth.

It seems to me, therefore, that any one who maintains that cold weather in North-Western Europe is more usual in an anticyclonic region than elsewhere, must show that these cold-producing anticyclones are anticyclones of a special kind, and lack the usual characteristics of an anticyclone, namely, a high barometer. This seems so unlikely that the onus of proof must be with those who maintain the theory.

The truth seems to be that cold weather is generally found to the south, and warmth to the north, of an anticyclone; that the region itself may partake of either characteristic, but is more likely to have an average temperature. Hence at Greenwich, where the winter average is 7° above the freezing point, an anticyclonic frost is unusual, as also are mild days with a temperature much over 40°.

Southerly winds, as a rule, accompany a falling barometer, and Westerly to North-westerly a rising one; thus the weather is generally warmer in the former than in the latter case. The erroneous conclusion seems to have been drawn that a high barometer is accompanied by cold, and a low barometer by warmth; but the deduction does not logically follow, a rising not being of necessity a high barometer, and is certainly opposed to facts in as far as the first part of it is concerned.

DISCUSSION.

The President (Mr. F. Campbell Bayard) said the thanks of the Society were due to Mr. Dines for the time and trouble he had expended over the paper.

Mr. C. Harding said that the Fellows had all learned to attach great value to any work done by Mr. Dines, but he (Mr. Harding) was inclined to take great exception to the conclusions arrived at in this paper. If low temperature in winter was not associated with a high barometer, what could be said of the question of wind in relation to cyclonic and anticyclonic conditions? It was not usual to expect a high barometer with a South-west wind, but a falling barometer and relatively high temperature; and, on the other hand, a rising barometer was frequently accompanied by a Northerly or North-easterly wind and falling temperature. It was certain that if Mr. Dines's theory proved to be correct, an all-round revision of the text-books would have to be undertaken.

Mr. F. J. Brodie said that in order to render such an inquiry thoroughly

convincing, it would be necessary to examine each individual barometer reading in the light of the isobaric chart for the time in question. He agreed with the author that a high monthly mean pressure indicated, as a rule, the existence of anticyclonic conditions; but in dealing with individual readings this was by no means the case. It must not be forgotten that the temperature in an anticyclone, and especially around its borders, depends very much upon which segment of the system the station happens to be in. If on its northern side, the prevailing winds will be Westerly or South-westerly, and the weather naturally mild; while on its southern side there will be a cool wind from the Eastward or North-eastward. With regard to the comparison made between the barometer at Berlin and the temperature at Geneva, the author remarked that with a high barometer at the former place the winds over Switzerland would be Easterly. This was scarcely the case, for while the barometer at Berlin might be high, it might at the same time be equally high or even higher at the southern station. There could be no doubt that the temperature in an anticyclone was largely regulated by the weather tendency existing at the time. In some winters—such, for instance, as that of last year—the general bias was in favour of mild weather, and the anticyclones observed were attended by temperatures little if any below the normal. In other winters, such as that of 1890-91, the tendency was all in the opposite direction, and in such seasons there could be little doubt that the greatest and most persistent cold was observed during the prevalence of anticyclonic conditions.

Dr. R. H. Scott thought there would be some difficulty in breaking up a belief which was so well established as that enjoyed by the several wind-roses for pressure, temperature, humidity, etc. The acknowledged meteorologists of eminence on the continent stood by the rule that "as the wind draws towards North-east the barometer rises and the thermometer falls; and when towards South-west the barometer falls and the thermometer rises." These principles were propounded by such an authority as Dr. Dove, and required a great deal of work to subvert them, if, indeed, such were possible.

Mr. G. J. Symons regretted the absence of Mr. Gaster, whose contribution to the discussion would have been valuable. He (Mr. Symons) thought that it would have been an advantage if Mr. Dines had carried the first table, dealing with the Greenwich observations, back as far as say 29 ins. He also thought in the diagrams that the points Mr. Dines meant more particularly to bring to their notice would be more obvious if the line of barometer were drawn across them. He thought Mr. Dines had succeeded in making a very good case as far as he had carried his research. With regard to an individual reading of 30·2 ins. being considered as proof that conditions were of an anticyclonic character, he, for his own part, should be surprised to see an isobar of that height in a circulation of any kind other than anticyclonic.

Major H. E. Rawson inquired if Mr. Dines intended his theory to hold in North-Western Europe only, or generally over the Northern Hemisphere. Had Mr. Dines thought it unnecessary in the first table to take into consideration the portion of the system which Greenwich was situated in? Also, had he considered the region from which the anticyclone came? It might be that it came from the Atlantic. If so, it would scarcely be expected to lower the temperature to the extent that one drawn from, say, Scandinavia or Siberia would do. He thought the thorough consideration of this point indispensable in an inquiry of this kind. Prof. Loomis had discussed a system which lasted 91 days, and brought high temperature for four successive weeks, after which it disappeared for an interval, reappearing with its old characteristic, viz. high temperature. This system came from Spain on both occasions. He welcomed this paper as tending to direct more attention to the question of anticyclones and the temperature associated with them.

Mr. W. H. Dines, in reply to Dr. Scott and Mr. Harding, said that he quite agreed with them that a North-east wind produced cold, and a South-west warmth, but notwithstanding the authorities quoted by Dr. Scott, he could not assent to the proposition that an anticyclone was equivalent to a North-east wind, and a cyclone to a South-west wind. The direction of the wind depended on the relative position of the high and low barometer, and not on its actual height. With reference to Mr. Harding's remark about the necessity for rewriting the text-books, he (Mr. Dines) thought it very necessary; for the Greenwich observations showed that during 50 years the height of the barometer at Greenwich during times of frost was below its average winter value, and for himself he preferred to believe in the accuracy of the Greenwich observations rather than in the opinions of the authors of the text-books. He had answered some of the points raised by Mr. Brodie in the paper. With reference to Mr. Brodie's contention about the curves of Fig. 4, viz. that the barometer, though high at Berlin, might have been still higher at Geneva during the cold winters at Geneva, this was completely negatived by the curves of Fig. 3, which showed that cold winters were not more frequent at Geneva when the barometer was high than at other times. In reply to Mr. Symons, he said that he should have liked to have worked up the whole series of the Greenwich values, but was deterred by the labour it would have involved. He considered that the readings above 30·2 ins. were sufficient for his purpose, namely, to show that at Greenwich frost and anticyclonic conditions were not equivalent terms. In reply to Major Rawson, he stated he had in no way investigated the source of the anticyclone, but had treated the question solely from the point of its presence or absence.

FURTHER CONTRIBUTIONS TO THE FOUNDATION OF A THEORY OF THE DAILY BAROMETRIC OSCILLATION.

By Dr. JULIUS HANN, Hon. Mem. Roy. Met. Soc.

[Translated from the *Meteorologische Zeitschrift*, October 1898, by R. H. Scott, D.Sc., F.R.S.]

Under the above title, which is possibly not quite a suitable one, I have recently furnished (*Sitzungsber. der K. Akad. der Wiss.*, Wien, vol. cvii., 1898) a contribution to our special knowledge of a phenomenon which is as yet imperfectly explained in many particulars, that of the daily oscillation of the barometer on the earth's surface, and especially on mountain-tops. The inducement which led me to undertake again this investigation is to be explained as follows. I held myself bound to discuss, at least in a partial way, the observations on the barometer range which had been carried on, mainly at my own suggestion, on the open sea, by the Austrian Imperial Navy. The very latest contributions which the Imperial Admiralty has handed in are by no means small, and it has not been possible, as yet, to submit them to discussion. The interest which the determination of the daily barometric oscillation over the oceans presented to me lay in the fact that I hoped

by means of such observations (combined with those on small, low oceanic islands) to arrive at the daily oscillation entirely undisturbed by local influences, *i.e.* at that part of it which covers the period of 24 hours; while, as is well known, the major portion of the regular diurnal oscillation, up to as far as the middle latitudes, has a double oscillation in the day, showing two maxima and two minima, and therefore has some resemblance to atmospherical tides.

I.—General Explanations of the Cause of the Daily Barometric Oscillation.

I venture to insert here, before dealing with my latest calculations, a few general explanations which will not be found in the paper I have quoted, and which thus may reach a wider circle of readers, and may therefore be of some utility. A brief explanation of the present condition of the mathematico-physical theory of the daily barometric oscillation appears to me to be well worth insertion in this journal.

I was myself convinced that all the attempts to explain the diurnal barometric oscillation by means of the daily variations of the meteorological elements at any one place, as attempted by Kreil, Blanford, Renou, and others, could lead to no conclusion; and I have published a series of papers giving a precise description of the phenomenon as manifested over the whole earth, at sea-level as well as at all elevations for which observations exist, and I have endeavoured to give the results in such a form as would be suited for the basis of a physico-mathematical theory. With this object I have represented all the results of observations in periodical functions, and have calculated the amplitudes and phase epochs of the individual waves, whatever was their period, and which when combined together produce the complex result of the daily barometric curve, such as presents itself to direct observation.[1]

[1] Hann, "Untersuchungen über die tägliche Oscillation des Barometers," *Denkschriften der Wiener Akademie*, vol. lv., 1889. Somewhat later appeared A. Angot's great and thorough work, "Étude sur la marche diurne du baromètre," *Annales du Bureau Central Mét. de France*, 1887. Both these papers treat of the regular appearance of the *double* daily oscillation, and in some measure also of the other oscillations, *on the earth's surface.* Hann: "Einige Resultate stündlicher meteorologischer Beobachtungen auf dem Gipfel des Fuji in Japan," *Wiener Sitzungsber.* December 1891; "Weitere Untersuchungen über die tägliche Oscillation des Barometers," *Denkschriften*, lix. Wien, 1892; "Beiträge zum täglichen Gange der meteorologischen Elemente in den höheren Luftschichten," *Wiener Sitzungsber.* January 1894. In these three papers I have sought to develop the theory of the diurnal barometric oscillation on mountains and peaks, inasmuch as the last have hitherto complicated and obscured the appearance of the whole phenomenon, and have given rise to many untenable theories. I have also shown that by a simple and elegant method we can calculate from the daily pressure curve on mountains the true diurnal curve of temperature in the strata below in both amplitude and phase epoch. The chief outcome of this calculation is that the amplitudes of the true daily thermometer range in the free atmosphere are much less than is shown by direct observations, and that the daily temperature curve, in so far as that is due to the heated surface of the earth, cannot be traced to a great height in the atmosphere. This result has already been in part confirmed by the recent balloon ascents (Hann, "Der tägliche Gang des Barometers an heiteren und trüben Tagen, namentlich auf Berggipfeln," *Wiener Sitzungsber.* June 1895). The difference between the barometer range on clear and cloudy days was first investigated by Lamont, and has more recently been set forth by Buchan, by utilising a much more copious supply of material. I have traced this difference back to differences in the amplitude and phase epoch of the diurnal pressure wave, on clear and cloudy days, and I think that I have detected the most probable causes of these modifications in the diurnal pressure curve in the varying conditions of weather (see *Meteorologische Zeitschrift*, 1896, Literaturbericht, p. 4).

The diurnal oscillation of the barometer, as we observe it, exhibits many details which are either unnoticed or even lost when this is resolved into two or even three harmonical constituents, *e.g.* the third maximum at night, which has been specially studied by Ragona, and also by Rykatcheff. This, however, causes no difficulty to us in undertaking the task of explaining the whole phenomena; in fact, it facilitates the work, as we deal first with the principal phenomena alone, and study the laws of its manifestation in space and time. This is the only method which has enabled us to make material progress in the comprehension and explanation of the whole problem.

I published a lengthy report on the great and valuable work of Rykatcheff on the daily oscillation of the barometer.[1] This work we may designate as the first comprehensive discussion of this puzzling phenomenon, and in it all the different theories which had been broached up to its date have been subjected to a thorough examination. In that report I have, in general terms, expressed the following views.[2]

I am of opinion that, speaking generally, the observed daily variation of wind and of temperature do not stand in as close a relation to the diurnal barometric oscillation as has hitherto been assumed. I think that this assumption is incompatible with the regular appearance of the phenomenon. If, *e.g.*, Rykatcheff says, "The fact, that the daily amplitudes of the barometer increase with approach to the equator and with advance from the ocean to the interior of the continents, is explained by the circumstance that the diurnal amplitudes of temperature also increase under the same conditions" (p. 120), I am of opinion that this can certainly not be the case; for how could it come about that, *e.g.* at Batavia, where the daily range of temperature is 5°·9 C., that of pressure is 2·7 mm.; whereas at Vienna, where the temperature range is 8°·0, that of pressure is only about one-third of the amount at Batavia; and further, how could it be that at sea in the tropics, where the temperature range, observed on board ship, is only 1°·5 (it is certainly less than that), the barometer oscillation is far greater (2 mm. and more) than in the temperate zone, even at stations where the daily temperature amplitude is from 10° to 15°? We had better deal with the action of the sun on the upper strata of the atmosphere, and treat this as the principal cause. The actinometrical observations show us that these upper strata absorb a considerable amount of heat. This diurnal heating action of the sun on the upper strata would harmonise far better with the general uniformity of the daily barometric oscillation along the different parallels of latitude, as well as with its general independence of weather. We need not quite exclude local influences, but these seem to be more of a secondary character.

Inasmuch as the *periodical* action of the sun's rays on the *upper strata* of the atmosphere, recurring day by day, must produce periodical movements of great regularity (an oscillation of the entire mass of the atmosphere), it is easy to see that this can explain the typical

[1] "La marche diurne du baromètre en Russie," *Repertorium für Meteor.* vol. vi. 1879. This paper gives the results of observations at a large number of stations, not only in Russia, in the form of deviations of the hourly means from the daily mean, and then discusses the complex phenomenon, without separating it into its component parts.

[2] *Met. Zeitschrift*, vol. xvi. p. 49 (1881).

character of the diurnal barometric oscillation, while the local differences of the earth's surface represent the modifying element.

Almost exactly a year later Lord Kelvin expressed a similar view of the cause of the daily barometric oscillation; but he has gone much further, and has shown how the problem should be attacked from the side of mathematical physics, and how the most puzzling feature of the diurnal range (the double daily oscillation) is to be explained. As this particular utterance appears in a paper of which the title gives apparently no hint of its relation to the causes of the diurnal barometric oscillation (the *Proceedings of the Royal Society of Edinburgh* are only published after an interval of a year or two), it was not until some years later that I became aware of this important utterance of the great English physicist on the theory of the daily barometric oscillation.[1]

This paper of Lord Kelvin's has been epoch-making in respect of the theory of the daily barometric oscillation, and so I give the words in the note.[2]

If we eliminate the non-periodical agencies from the daily barometric curve, we can represent the latter almost completely by the superposition of two waves of pressure, of which one has a period of an entire day, the other of only half a day. The whole day period comes out much more decidedly on clear than on cloudy days. It has a small amplitude over the ocean, but a very great one over heated land surfaces and in mountain valleys, so that it undoubtedly proves itself, by its striking local peculiarities, to be related to the diurnal range of temperature. The semidiurnal wave shows itself at all places with a regularity quite unknown among other meteorological phenomena: along each parallel of latitude it comes out with almost uniform amplitude and phase epoch. The latter is (with reference to local time) almost quite constant up into high latitudes, whereas the amplitudes steadily decrease with approach to the Pole. Any relation between this pressure oscillation and the diurnal range of temperature is very obscure.

Now it is very remarkable that the double daily oscillation is the principal phenomenon. It exhibits the greatest amplitudes, and over equatorial oceans is almost the only one represented.

[1] "On the Thermodynamic Acceleration of the Earth's Rotation," by Sir W. Thomson (*Proceedings Royal Society of Edinburgh*, vol. xi. p. 396).

[2] "It is a very remarkable result of this analysis, that the amplitude A_2 of the semidiurnal term is for most places considerably greater than the A_1 of the diurnal term. The cause of the semidiurnal variation of barometric pressure cannot be the gravitational tide-generating influence of the sun, because, if it were, there would be a much larger lunar influence of the same kind, while in reality the lunar barometric tide is insensible or nearly so. It seems therefore certain that the solar diurnal variation of the barometer is due to temperature. Now the diurnal term, in the harmonic analysis of the variation of temperature, is undoubtedly much larger in all places than the semidiurnal. It is then very remarkable that the semidiurnal term of the barometric effect of the variation of temperature should be less, and so much less as it is, than the diurnal. The explanation probably is to be found by considering the oscillations of the atmosphere, as a whole, in the light of the very formulas which Laplace gave in his *Mécanique Céleste* for the ocean, and which he showed to be also applicable to the atmosphere.

"When thermal influence is substituted for gravitational, in the tide-generating force reckoned for, and when the modes of oscillation corresponding respectively to the diurnal and semidiurnal terms of the thermal influence are investigated, it will probably be found that the period of free oscillation of the former agrees much less nearly with 24 hours than does that of the latter with 12 hours; and that therefore, with comparatively small magnitudes of the tide-generating force, the resulting tide is greater in the semidiurnal term than in the diurnal."

If we analyse the diurnal variation of temperature in the same way as that of pressure, we obtain a wave of temperature which appears twice in the course of the day, but its amplitude is very slight (only $\frac{1}{5}$ or $\frac{1}{8}$) as compared with the amplitude of the diurnal temperature wave.[1]

Some examples may here be given. If we count the time from midnight ($x=0$ for midnight), we obtain the following expressions for diurnal oscillation.[2]

I. *Equatorial Pacific.* *Lat.* 6° (40 *days*).

Pressure . . $759{\cdot}4\text{ mm.}+0{\cdot}29\text{ mm.}\sin(2^\circ{\cdot}4+x)+1{\cdot}01\text{ mm.}\sin(161^\circ{\cdot}0+2x)$
Temperature . . $27^\circ{\cdot}8\text{ C}+0^\circ{\cdot}87\sin(250^\circ{\cdot}0+x)+0^\circ{\cdot}11\sin(73^\circ{\cdot}8+2x)$

II. *Tropical Pacific.* *Lat.* 16° *S.* (40 *days*).[3]

Pressure . . $760{\cdot}5\text{ mm.}+0{\cdot}30\text{ mm.}\sin(25^\circ{\cdot}7+x)+0{\cdot}80\text{ mm.}\sin(160^\circ{\cdot}1+2x)$
Temperature . . $27^\circ{\cdot}6\text{ C}+1^\circ{\cdot}39\sin(239^\circ{\cdot}8+x)+0^\circ{\cdot}31\sin(76^\circ{\cdot}9+2x)$

III. *Subtropical Pacific.* *Lat.* 33° *S.* (64 *days*).

Pressure . . $761{\cdot}7\text{ mm.}+0{\cdot}22\text{ mm.}\sin(284^\circ{\cdot}9+x)+0{\cdot}50\text{ mm.}\sin(158^\circ{\cdot}6+2x)$
Temperature . . $19^\circ{\cdot}2\text{ C}+0^\circ{\cdot}97\sin(226^\circ{\cdot}9+x)+0^\circ{\cdot}25\sin(27^\circ{\cdot}7+2x)$

IV. *Temperate Zone* (*Vienna*). *Lat.* 48° 12′ *N.*, 194 *metres.* *Whole year.*

Pressure . . $744{\cdot}5\text{ mm.}+0{\cdot}22\text{ mm.}\sin(359^\circ{\cdot}6+x)+0{\cdot}31\text{ mm.}\sin(141^\circ{\cdot}4+2x)$
Temperature . . $9^\circ{\cdot}7\text{ C}+2^\circ{\cdot}86\sin(223^\circ{\cdot}2+x)+0^\circ{\cdot}51\sin(32^\circ{\cdot}1+2x)$

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1 I shall discuss later on the importance of such an analysis of the daily march of temperature—a discussion which many people consider useless.

2 Perhaps I shall please some of my readers if I relieve them of some trouble by giving a slight discussion of the above equations, so that they shall not fail in their object.

The constant angle in the brackets fixes the phase epochs of the diurnal or semidiurnal wave of pressure or temperature. It represents the value thereof for $x=0$, *i.e.* for midnight in our case. I shall in future always designate these by A_1, A_2, A_3, etc. If we introduce definite values for the variable angle x, we shall obtain the required ordinate for definite epochs. If it be wished to obtain the values for hour intervals, we have to insert for x in the first term, 15°, 30°, 45°, etc., in the second, 30°, 60°, 90°, as each hour interval corresponds to 15° in the first, and to 30° in the second term. We might therefore insert for x in the first term, A_1+15h, in the second, A_2+30h, where h represents the hour.

The maximum (the flood) occurs with the first *diurnal* wave at $A_1+15h=90^\circ$. If A_1 is almost equal 0, the maximum (the flood) comes at 6 a.m., the minimum (the ebb) at 6 p.m.; for then $A_1+15h=270^\circ$. In the diurnal temperature wave, where, in I., $A=250^\circ$, we have as the condition for the epoch of the maximum, $250^\circ+15h=90^\circ$, *i.e.* $h=-\frac{160}{15}=10{\cdot}7$, *i.e.* $12-10{\cdot}7=1{\cdot}3$ hours after noon. The minus sign indicates that the maximum occurs 10·7 hours before midnight. If we were looking for the hour of the minimum, we should insert $250^\circ+15h=270^\circ$, which would give us $h=1{\cdot}3$ after midnight—the same result.

If we are in search of the epoch of the flood, the maximum, in the second, the semidiurnal wave, we must insert in cases I. and II., $160^\circ+30h=90^\circ$, so that $h=-\frac{70}{30}=-2{\cdot}4h$ approximately, so that it occurs 2·4h before midnight, or at 9·6h—in round numbers, at 9.30 p.m. The minimum epoch we get from $161^\circ+30h=270^\circ$, so that $h=3{\cdot}6h$ after midnight. The turning-points of the barometer in the semidiurnal oscillation, the principal phenomenon, are therefore in the tropical Pacific 9.30 a.m. and p.m. for the maximum, 3.30 a.m. and p.m. for the minimum.

In the subtropical Pacific (and, as we shall see, over the sea in the middle latitudes), the phase angle A_1 of the diurnal wave lies in the third quadrant. Then we must insert for the epoch of the maximum, $285^\circ+15h=90^\circ$, or $h=-13h$, *i.e.* 11 a.m. The maximum of the diurnal wave occurs $\frac{285-227}{15}=\frac{58^\circ}{15}=4$ approximately, so it occurs 4 hours *before* the maximum of the diurnal temperature wave. An *increase* of the constant phase angle implies an *earlier* occurrence of the extremes by one hour for every 15° in the first term, by 30° in the second. A *reduction* in the phase angle indicates a *retardation* of the extremes.

The coefficients of the sine terms give the amplitudes of the waves, and we shall designate these later by a_1, a_2, a_3, etc. In the tropical Pacific the whole variation in the diurnal pressure wave is 0·6 mm., but in the semidiurnal wave 2·0 mm. At Vienna these amplitudes are 0·4 and 0·6 mm., and not nearly so strongly contrasted.

3 The amplitude of temperature is affected (raised) by proximity to land (islands).

The amplitude of the semidiurnal barometric oscillation [*i.e.* of the curve $a_2 \sin(A_2 + 2x)$] is, as will be seen, up to lat. 48°, greater than that of the diurnal oscillation; over the equatorial ocean the relation of a_2 to a_1 is about 3. The amplitude of the semidiurnal portion of the daily temperature range is, on the other hand, only from $\frac{1}{8}$ to $\frac{1}{4}$ of the amplitude of the diurnal temperature wave.

We see further that the maximum of the daily barometric wave between the tropics, over the ocean, as well as over the continents, almost invariably comes at 6 a.m., and the minimum at 6 p.m., as the constant angle A_1 comes out close to 0° (or nearly at 360°). Over the ocean in higher latitudes, and on the coasts, as well as on islands, A_1 generally lies in the third quadrant, and the maximum occurs later in the forenoon, and so approaches the daily maximum of temperature (within from 2 to 4 hours).

The floodtime of the semidiurnal barometric wave is given by the constant angle (A_2) 140° to 160°, and is very constant over the entire globe. If A_2 be 140°, it corresponds to the tropical hours 10.20 max. and 4.20 min.; if A_2 be 150°, the tropical hours 10 and 4; and if A_2 be 160°, the tropical hours 9.40 and 3.40. A change of 1° in the angle corresponds to a change of 2 minutes in the phase time.

The most important conclusion which we gather from the foregoing equations is, that over the tropical oceans very small temperature oscillations accompany very great pressure oscillations. The diurnal variation of temperature at sea is certainly considerably less than that which results from our equations, because the observations are strongly influenced by the heating of the ship's hull. It is probable that the true semiamplitude in the open sea is not greater than 0°·5 C.[1]

When Lord Kelvin draws attention to the discordance in magnitude between the diurnal and semidiurnal temperature waves, and the corresponding amplitudes of the pressure wave, he gives the following explanation to remove the contradiction between this and the thermal origin of the daily barometric oscillation:—

"The explanation probably is to be found by considering the oscillations of the atmosphere, as a whole, in the light of the very formulas which Laplace gave in his *Mécanique Céleste* for the ocean, and which he showed to be also applicable to the atmosphere. When thermal influence is substituted for gravitational in the tide-generating force reckoned for, and where the modes of oscillation corresponding respectively to the diurnal and semidiurnal terms of the thermal influence are investigated, it will probably be found that the period of free oscillation of the former agrees much less nearly with 24 hours than does that of the latter with 12 hours; and that therefore, with comparatively small magnitudes of the tide-generating force, the resulting tide is greater in the semidiurnal term than in the diurnal."

Dr. M. Margules has undertaken the difficult and laborious work,

[1] The diurnal range of temperature, as far as it is represented by a whole-day wave, reaches its maximum shortly after 1 p.m. (on the open sea $A_1 = 250°$), or up to 3 p.m. ($A_1 = 225°$); the second semidiurnal wave (A_2 lies always in the first quadrant, so that the first maximum, $A_2 + 2x = 90$, comes soon after midnight) pushes on the nocturnal minimum towards sunrise, according to observation. This result is a consequence of the character of the daily march of temperature, which is principally governed in the day time by the height of the sun (*i.e.* by insolation), in the night time solely by the radiation of heat, which forces on the temperature minimum towards sunrise.

following out Lord Kelvin's suggestion, of calculating, on the lines laid down by Laplace, the oscillations in the earth's atmosphere as they might be due to its periodical warming.[1]

The calculation is simplest for a shell of air at rest if friction is neglected; the constant oscillations of the air in a spherical shell at rest have been calculated by Lord Rayleigh; Dr. Margules has solved the problem for a rotating shell of air subject to friction, and by this has rendered it possible to apply the results to the explanation of the daily barometric oscillation.

We shall now give an extract from the introduction to Dr. Margule's second paper, although it has no direct relation to the problem of the diurnal barometric oscillation, because it deals with the simplest (the zonal) oscillations in a rotating shell.

"If we consider the earth's surface to be quite homogeneous, and covered with a shell of air of small thickness, then each couche remains in relative rest if the pressure remains constant. If we now suppose that either diminished or increased pressure appears in a narrow zone, then movements and changes of pressure set in, and our task is to calculate these. Lord Rayleigh has shown for the air in a spherical shell which is at rest, that in a frictionless system the movement resolves itself into a series of fixed oscillations. The extension of the calculation to the case of friction proportional to the velocity (in a couche of air of slight depth) is easily carried out. In whatever manner the zonal initial conditions are brought about, the movement may be held to be composed of fixed oscillations which are dying away, and of movements which are extinguishing themselves without oscillation. In a frictionless system of a rotating spheroidal air-shell, every movement produced by zonal initial conditions is composed of fixed oscillations and of stationary movements along the parallel circles. If we introduce friction, we have extinguishing oscillations and extinguishing movements along spiral paths. The latter move from the regions of high to those of low pressure.

"In the usual meteorological calculations, which are necessarily very imperfect, only such movements as take place along the gradient are noticed, and to these the well-known law of Buys-Ballot applies. If, however, movements existed which were directed from areas of low to areas of high pressure, this law would no longer be true.

"It is, however, probable that there are movements against the gradient; that the movements initiated by differences of pressure do not come to an end when the gradient ceases to exist, but go on in the same direction, owing to inertia, so that the region which at first had low pressure becomes a region of high pressure, and thus oscillations are set up. These do not obey Buys-Ballot's Law.

"In fact, Buys-Ballot's Law is found to be confirmed all over the globe in an overwhelming majority of cases, so that the few exceptions to it are attributed to the imperfection or the uncertainty of the observations.

"The conditions in an atmosphere of considerable height, in comparison with the abstract conception of a very thin shell, may increase the probability of the existence of the law, but even then oscillations are

[1] "Über die Schwingungen periodisch erwärmter Luft," *Sitzungsb. Wien. Akad.* March 1890. "Luftbewegungen in einer rotirenden Sphäroidschale," *Sitzungsber. der Wien. Akad.* April 1890, January and December 1893.

not quite excluded. If the friction is considerable, the oscillatory movements disappear much more rapidly than the expansive ones, and so the latter take the pre-eminence."

Dr. Margules shows, in the first of the papers cited, that the period of free oscillations in a rotating spherical shell of air (of the usual temperature) is nearly 12 hours. If we take for the spherical shell of air the actual rotation of 24 hours, it suffices to assume a mean (absolute) temperature of the atmosphere of 268° (– 5° C.) in order that the oscillations thereby produced, and which have only half the duration of the rotation, shall attain a very great amplitude. Accordingly, a very small semidiurnal temperature wave will suffice to produce a very great pressure wave. The phases of both are accordant at temperatures under 268°; in other cases they are opposed. If the calculation leads to values too minute to have any real importance, it certainly follows that much smaller temperature oscillations will suffice to produce semidiurnal pressure waves of the same magnitude as the diurnal ones.

Margules, in his third paper, investigates the influence of friction on waves which are caused by temperature oscillations or by periodical forces. For this object the calculations which have been carried out in the first paper only for frictionless air movements are treated in more detail. The *general* solution of the work of calculating the pressure waves which are produced over a uniform earth surface by temperature waves advancing westwards is far too difficult. The author finds himself obliged to resolve the work into some simple problems, and to deal with these. The results at which Dr. Margules has arrived are of fundamental importance for the theory of the diurnal barometric oscillation.

In so far as the daily march of temperature in the lower strata (up to about 4000 metres) is considered (a very rapid decrease of amplitude in the daily temperature variation is assumed—an amplitude of 3°, at 900 metres only 1°, at 2000 metres only 0°·5), it is quite possible to set up a theory of the diurnal pressure oscillation which will accord very well with observations.[1]

The diurnal pressure wave has a more local character, as has also the daily rise of temperature, and these, at least in the middle and high latitudes, only show themselves daily with constant amplitude over isolated and relatively small areas. Like the diurnal, so also the semidiurnal temperature waves in the lower strata produce locally irregular pressure waves, whose amplitudes are in the same proportion less than the diurnal waves, as in the case of the temperature waves. These irregular oscillations interfere with the regular (and greater) semidiurnal wave.[2]

It follows from the calculations on pp. 38-42 of the paper quoted, that if we assume in an upper stratum of the atmosphere a regular daily range of temperature to exist, which may be represented by a sum of westward-moving waves of periods of 24, 12 . . . hours' duration, the diurnal pressure wave at the ground-level comes out small, but the semidiurnal pressure wave exhibits an amplitude which is very great in comparison with the corresponding temperature wave. If we knew the daily range of

[1] Pages 48-52 of the paper quoted. At page 37 the author deals with the modifications which the diurnal and the semidiurnal barometer waves exhibit in mountain valleys.

[2] Angot, in his paper quoted above, has attempted to separate out these constituents of the observed semidiurnal wave.

temperature in the upper strata, the equations proposed by Dr. Margules would lead to a nearly complete solution of the problem of the daily barometric oscillation.

These explanations ought at all events to be sufficient to direct attention to the importance of Dr. Margules's mathematical investigations, of which no notice has been as yet taken in the *Meteorologische Zeitschrift*.

I have, however, received from some of my colleagues certain objections to Lord Kelvin's hypothesis of the origin of the double daily barometric wave, and these seem to me so important that I shall briefly touch on them in this place.

First, it is objected that it is questionable if the march of temperature in the upper strata is precisely of the same character as in the lower, on which latter the hypothesis is based; and, secondly, that the double daily temperature wave is only a result of calculation, a mathematical fiction, which cannot serve in the explanation of a real phenomenon. There is, in reality, no daily variation of temperature with two maxima and minima; and if we, in spite of this, obtain a double daily temperature wave, because we insist on representing the daily march of temperature by a series of sines, this forced mathematical form can never serve to explain an observed phenomenon, whereas for this some real natural process must be sought for as a cause. I think that in the foregoing words I have given reasonably fairly the sense of the objections laid before me.

As to the first of the foregoing objections, I would state my own conviction that the daily temperature range in the upper strata has the same general form as that in the lower. The two distinct causes which bring it about are the same—the action of insolation by day and that of radiation by night. The former causes the maximum to occur shortly after the maximum altitude of the sun; the latter puts off the minimum to the epoch immediately before sunrise. The daily curve must therefore be asymmetrical, and composed of two parts which do not follow the same law. If we resolve it into a sine series, we always find a diurnal wave of great amplitude, and a semidiurnal wave with much smaller amplitude, *i.e.* the result on which Lord Kelvin's hypothesis rests.[1]

In the highest strata of which we know approximately the range of temperature, this daily range takes in fact the same course as below, in general. The expressions for the daily range of temperature at the top of Pike's Peak, 4308 metres (relatively about 2500 metres), and in the strata between the Obir summit (2140 metres) and the summit of the Sonnblick (3106 metres), at an elevation of 2620 metres (relatively about 2100 metres), are, *e.g.*, as follows:—

Daily Temperature Range, Yearly Means.

Pike's Peak . .	$-7^{\circ}\cdot7+1\cdot78 \sin(229\cdot3+x)+0\cdot51 \sin(43\cdot4+2x)$
Obir—Sonnblick . .	$-3^{\circ}\cdot3+0\cdot84 \sin(227\cdot4+x)+0\cdot18 \sin(33\cdot7+2x)$

The latter expression represents the true march of temperature in high strata better than the former, because the ground surface has not such

[1] Dr. Trabert has made an attempt to calculate the daily range of temperature in the upper strata: "Über die Grösse der Temperaturwelle, welche in den oberen atmosphärischen Schichten die Erde umkreist," *Meteor. Zeitschrift*, xxix. (1894), p. 440. He finds the amplitude of the diurnal temperature variation about 0°·5 C.; the maximum occurs about 6 p.m.

an influence on it. However, the two expressions agree almost exactly in their form, and prove that in the upper regions the same general march of temperature prevails as at the earth's surface, especially as concerns the semidiurnal portion of the temperature wave, which specially interests us at this juncture. I have no doubt that these constituents of the daily march of temperature are present in the very highest strata.[1]

As regards the second objection, which is that the daily wave of temperature is not in reality a double daily oscillation, and cannot therefore be the cause of a double pressure wave, it seems to me that this objection rests on a misconception of the causes which can possibly give rise to constant oscillations in a fluid or gaseous medium. We may fairly trust so skilled a physicist as Lord Kelvin not to have misconceived the nature of the problem. It may seem, therefore, to be almost a presumption on my part to add some remarks which appear to me to put the matter in a somewhat clearer light.

If a limited mass of fluid is set in simple pendulum-like oscillations, their amplitudes are governed by the given conditions of the fluid or the gas (dimensions, temperature). If the impulse is a single powerful one, such as that which gives rise to seiches in lakes,[2] it is perfectly immaterial how it goes on: the mass of water takes up always the same pendulum movement, in which it can move in virtue of its dimensions (the length and depth of its basin).

If the impulse recurs periodically, then oscillations of that period are *forced* to occur, even if these do not coincide with any of the forms of oscillation which belong to free waves. This holds if the impulse represents a simple sine wave. In other cases the following must be considered. Fourier showed mathematically that any periodical form of oscillation (or wave of any form) can always be resolved into a sum of simple pendulum oscillations (waves), and that their number of oscillations are 1, 2, 3 times as great as the number of oscillations of the given form of movement, and only in one *single* manner. When any periodically recurring impulse of any form is resolved by Fourier's harmonic analysis into pendulum oscillations, each portion of these produces a forced oscillation of the same period in the mass of fluid. But the amplitudes of these forced waves do not preserve the same proportion to each other as those of the waves which produce them. If the period of an exciting wave is nearly the same as that of a free wave in

[1] I shall here give the equations of the diurnal temperature range in the different seasons:—

Pike's Peak.

Winter	$1{\cdot}56^{\circ} \sin(234{\cdot}7+x)+0{\cdot}60 \sin(48{\cdot}4+2x)$
Spring and Autumn	$1{\cdot}82 \sin(225{\cdot}5+x)+0{\cdot}54 \sin(35{\cdot}2+2x)$
Summer	$1{\cdot}93 \sin(232{\cdot}4+x)+0{\cdot}39 \sin(57{\cdot}5+2x)$

Stratum between the Obir Summit and Sonnblick Summit.

Winter	$0{\cdot}39^{\circ} \sin(228{\cdot}1+x)+0{\cdot}17 \sin(40{\cdot}2+2x)$
Spring	$0{\cdot}98 \sin(223{\cdot}3+x)+0{\cdot}18 \sin(33{\cdot}7+2x)$
Summer	$1{\cdot}38 \sin(228{\cdot}2+x)+0{\cdot}17 \sin(23{\cdot}6+2x)$
Autumn	$0{\cdot}64 \sin(231{\cdot}4+x)+0{\cdot}19 \sin(36{\cdot}3+2x)$

I should think that the diurnal temperature wave in the free air in the upper strata comes nearer to that observed on mountain-tops in winter than in summer.

[2] *Vide* my *Allgemeine Erdkunde*, i. 5, Aufl. p. 308.

the liquid, the resulting forced oscillation will attain a disproportionately great amplitude.

This principle may be applied to the constant oscillations of our atmosphere, which are produced by a periodical impulse, *i.e.* by the variation of temperature which recurs uniformly day by day. If the atmospherical envelope of our earth, with its conditions of space and of temperature, is most easily set in oscillations of a semidiurnal period, the semidiurnal portion of its exciting cause, the daily temperature wave, will be the most active. It does not matter whether this semidiurnal temperature wave has a real independent existence.

II. Results of Observations.

After these general explanations, I shall give some observational results from my paper, as to the behaviour of the diurnal and the semidiurnal barometric oscillations, and also (very briefly) as to the waves occurring three times a day.

A. *The Diurnal Barometric Oscillation.*[1]

The diurnal barometric oscillation is subject to the greatest disturbance as to time and locality, for all meteorological phenomena exhibit principally a diurnal period, and exert some influence on the barometric oscillation. All local modifications of meteorological processes, as well as all temporary changes of weather, have an influence on the diurnal constituents of the daily barometric oscillation. Accordingly, this bears clear traces of all irregularities, whether in space or time, of meteorological phenomena; and on this account adjacent localities are found to exhibit great differences, both in amplitude and in epoch, in the diurnal barometric oscillation. The annual period of their amplitudes, as well as of their phase epochs, is often very irregular and locally different.

The greatest influence is exerted by the periodical diurnal transference of masses of air, such as are manifested by land and sea breezes, and by mountain winds. In the same way the altitude of a place has a great influence on the amplitude and the phase epoch of the diurnal oscillation, but not the absolute height above sea, but the relative height, or, more accurately speaking, the depth, of the underlying air strata, in so far as these exert an influence on the pressure at the place, owing to their daily upheaval and descent. These things make it extraordinarily difficult to discover the constant portion of the diurnal barometric wave, which varies with latitude and season, among the interferences of the local diurnal barometric waves therewith.

We can only expect to be able to observe the "normal," or, as I

[1] I may again repeat that all the reasoning which follows deals with the representation of the diurnal barometric curve by means of the so-called harmonic series of the form:

$$p_1 \cos x + q_1 \sin x + p_2 \cos 2x + q_2 \sin 2x + p_3 \cos 3x + q_3 \sin 3x,$$

or of the form deduced therefrom:

$$a_1 \sin (A_1 + x) + a_2 \sin (A_2 + 2x) + a_3 \sin (A_3 + 3x) +$$

Each term represents one of the harmonic constituents, which by their interference produce the observed wave. The angle constants A give the phase times, the numerical coefficients a the amplitudes of the waves, diurnal, semidiurnal, etc. We take $x = 0$ for midnight.

Angot, in his paper, takes a series of cosines for his representation; this is also done frequently in England. The angular constant A must then be increased by 90°.

may say, the "terrestrial," diurnal barometric oscillation over a region of the earth's surface which is quite uniform, and therefore affords no opportunity for local convection currents. It is specially interesting to learn the magnitude and properties of this diurnal wave, in so far as this is a portion of the general daily oscillation of the atmosphere. This general diurnal oscillation I shall, for brevity, call the *terrestrial diurnal oscillation.*

Such uniform extended regions of the earth's surface, where we have least reason to fear interference of local pressure waves with the normal diurnal wave, are only to be found in the vast tracts of the ocean, far away from any land. Accordingly, observations or registration of pressure on board ships in the open sea, or on very small, low oceanic islands, are therefore our only chance to gain a knowledge of the properties of the terrestrial diurnal wave.

This was the reason I moved the authorities to arrange for hourly observations every day to be taken in Austrian Mission ships, and of these a portion is discussed in the present paper, as well as the records from the little coral island of Jaluit (5° 55′ N. lat., 169° 40′ E. long.).

In order to show the disturbed conditions of the diurnal wave, I have also discussed the observations from the rocky island Pelagosa in the central Adriatic, and from Ponta Delgada, etc., as well as those from Pike's Peak and from Mont Blanc.

In my paper in the *Sitzungsberichte* of the Vienna Academy (January 1898) I have calculated the hourly barometric observations on shipboard, and have obtained the following mean results. The data on which these mean values have been obtained is given in that paper (pp. 21-48).

THE TWO FIRST HARMONIC CONSTITUENTS OF THE DIURNAL BAROMETRIC OSCILLATION, ACCORDING TO SHIP OBSERVATIONS.[1]

Latitude.	Days.	A_1	A_2	a_1	a_2
4·5°	147	5·2	155·0	·262	·875
11·1	58	4·2	158·8	·265	·811
15·8	61	358·0	157·7	·268	·805
23·0	125	330·6	149·4	·115	·620
33·8	118	320·5	155·4	·148	·489
35·9	234	241·5	154·6	·140	·385
40·7	70	291·8	155·2	1·85	·234
		Mediterranean Sea.			
37·0	40	281·3	127·5	·342	·372

The observations from which these calculated results have been derived are as yet insufficient to lead to reasonably secure conclusions, but as far as they agree *inter se* they justify the following statement.

On the open sea, near the Equator, the diurnal barometric wave has a phase time which is given by the angle constant of about 5°, *i.e.* the flood occurs at 5.40 a.m., and the amplitude of the wave is a little less than 0·3 mm.

These are shown to be the conditions of the terrestrial diurnal wave

[1] The table (p. 52) contains the main results of the calculations of hourly (and bi-hourly) barometric observations on board ship, which are given in my paper :—

by the observations taken for a whole year on the small coral island Jaluit in lat. 5° 55′ N.

Daily Barometric Oscillation at Jaluit.

$$0{\cdot}336 \text{ mm. } \sin(23° + x) + 0{\cdot}840 \text{ mm. } \sin(165° + 2x).$$

The amplitude here is somewhat greater and the phase time is earlier, and the flood (the barometric maximum) occurs at 4.30 a.m. Twenty days' direct observations with a mercurial barometer gave a result in perfect accordance with the ships' observations:

$$0{\cdot}270 \text{ mm. } \sin(4°{\cdot}7 + x) + 0{\cdot}823 \text{ mm. } \sin(157°{\cdot}3 + 2x).$$

I am therefore of opinion that, according to the observations which are as yet available, the terrestrial diurnal wave at the Equator has an amplitude of 0·3 mm. (*i.e.* about one-third of the amplitude of the semi-diurnal wave), and the phase time $A_1 = 5°$ (the maximum is about 5.30 a.m.).

As latitude increases, the phase time grows later and later, so that between the parallels of 23° and 24° the phase time is determined by the angle of about 325° (flood time 8.20 a.m.). I do not venture to assert that in higher latitudes the phase time is as much retarded as our table would appear to show. The proximity of the ships' positions to the land may have produced some influence (according to ships' observations, the flood time in latitude 38° is 1 p.m.). It would be very interesting to find out for certain if the phase times of the terrestrial diurnal oscillation are really reversed in the middle latitudes.

The amplitudes of the diurnal barometric wave at sea are quite small in the middle latitudes, and scarcely exceed 0·15 mm., but the amount

Collection of some Observational Results of the Diurnal Range of the Barometer over the Ocean.

Ship.	No. of Days.	Lat. °	p_1	q_1	p_2	q_2	A_1 °	A_2 °	a_1	a_2
Novara	35	4·5	·088	·336	·337	−·918	10·7	159·8	·347	·978
Challenger	37	3·8	·002	·225	·378	−·697	5·1	151·5	·226	·793
Saida	26	4·0	·018	·311	·284	−·802	3·3	160·5	·311	·851
Donau	49	5·9	−·007	·164	·464	−·746	357·6	148·1	·164	·879
Novara	40	8·0	North Indian Ocean				344·7	153·9	·399	·995
Aurora	55	9·0					347·5	170·1	·380	·920
Novara	40	10·0	·023	·212	·291	−·751	6·2	158·8	·213	·805
Saida	18	12·0	·002	·368	·296	−·768	0·3	158·9	·368	·822
Novara	40	16·5	·054	·306	·274	−·770	10·0	160·4	·311	·817
Zrinyi	10	14·0	...	...	...	...	291·9	153·6	·100	·904
Saida	11	15·0	·077	·255	·318	−·576	16·8	151·1	·266	·658
Challenger	30	22·4	−·017	−·002	·260	−·504	263·3	152·7	·017	·566
Zrinyi	13	22·4	...	...	...	...	318·6	156·3	·173	·754
Saida	14	26·0	·136	·138	·295	−·504	44·6	149·8	·194	·583
Donau	68	22·7	−·026	·128	·348	−·515	348·7	146·0	·130	·622
Novara	64	33·5	−·213	·057	·182	−·463	285·0	158·6	·220	·498
Novara	30	33·5	−·043	·067	·268	−·338	327·3	141·6	·080	·431
Zrinyi	24	34·8	...	...	...	...	24·8	162·9	·072	·529
Novara	20	37·5	−·037	−·224	·197	−·354	189·7	150·9	·223	·405
Challenger	141	36·0	−·117	−·001	·172	−·332	269·5	152·6	·117	·373
Saida	50	35·0	·083	·109	·163	−·358	37·3	155·5	·137	·394
Donau	23	35·7	·057	−·140	·103	−·380	157·9	164·8	·151	·394
Novara	40	39·0	−·137	·002	·100	−·168	270·8	149·2	·137	·195
Saida	30	42·5	−·171	·158	·088	−·260	312·7	161·3	·233	·274
Donau	34	39·5	−·104	−·097	·043	−·310	227·0	172·1	·142	·313

of material which has been worked up in the present paper is not sufficient to give us the means of fixing more accurately the relation between the amplitude and the geographical latitude.

The diurnal barometric wave over inland seas is disturbed by the daily transference of air from land to sea and back again (*e.g.* in the Mediterranean), and has a greater amplitude and retarded phase epochs. The semidiurnal wave is also disturbed in the same way, as we shall see later on.

The most interesting result of the year's barometer readings at Jaluit is the following:—

The angle constant A_1 (the phase time) and the amplitude (a_1) of the diurnal barometric wave have the same yearly period as the corresponding elements of the double daily oscillation.[1]

The terrestrial diurnal wave has therefore the same yearly period as the semidiurnal oscillation. It would be very desirable to control this important result by pressure observations on another small low island close to the Equator.[2]

Finally, the terrestrial diurnal barometric wave appears to have the following form at the Equator:—

$$0 \cdot 3 \text{ mm. } \sin (5^\circ + x).$$

Its phase times and amplitudes have the same yearly period as that of the double daily barometric oscillation. The phase times are retarded with increase of latitude, and the amplitudes appear to decrease slowly under the same conditions.

This is so far the whole result which I have been able to deduce from the material at my disposal, and which I have calculated as regards the properties of the terrestrial diurnal barometric wave.

The Diurnal Barometric Oscillation when it is more or less disturbed.

The subjoined statements may be made as regards the *mean* behaviour of the diurnal wave when more or less disturbed by interference with local diurnal waves, but they cannot lay claim to universal applicability, for the result is rather a chance one. (It has been determined from the character of the stations situated all over the globe, which are neither numerous nor equally distributed.)

[1] Jaluit, Harmonic Constants of the Diurnal Oscillation of the Barometer:—

	Observed.					Calculated.			
	A_1	A_2	a_1	a_2		A_1	A_2	a_1	a_2
January	19·5	164·1	·285	·808		22·4	162·2	·345*	·828*
February	19·6	159·2	·429	·850		20·2*	160·9*	·360	·845
March	22·1	163·4	·378	·897		21·4	162·9	·377	·893
April	27·5	165·2	·376	·906		24·2	165·4	·365	·910
May	15·0	164·9	·277	·866		25·5	165·3	·316	·865
June	28·3	164·7	·306	·778		24·1	162·4	·261	·786
July	18·6	157·1	·258	·765		22·1*	160·0*	·243*	·744*
August	26·5	161·9	·249	·751		22·3	161·0	·276	·777
September	22·5	166·3	·311	·875		25·5	165·5	·335	·859
October	29·7	169·7	·374	·917		29·1	169·7	·375	·918
November	33·7	169·1	·398	·895		29·9	170·1	·376	·913
December	30·6	166·3	·343	·887		26·8	166·5	·355	·862
Year	23·3	164·8	·336	·840	Mean	24·5	164·3	·332	·850

[2] On the island of Ascension, lat. 7°·9 S., there is only an indication of such a periodicity, but as the island is mountainous no further conclusions can be based upon the observations.

The phase times are fixed by the angle $A_1 = 10°$ approximately on the general average, both at continental and at maritime stations (we shall shortly learn what happens on islands and on many coasts). This corresponds to a flood time at 5.20 a.m. Accordingly, the mean phase time of the diurnal barometric wave appears to be subject to only slight disturbance. It is, in fact, nearly normal even in those mountain valleys where the amplitude of the wave attains an enormous magnitude (*e.g.* summer).

	Latitude.	A_1	a_1
Botzen	46° 30′	18°·6	1·39 mm.
Klagenfurt . . .	46° 37′	21°·2	0·78 ,,
Death Valley . . .	36° 5′	352°·6	2·01 ,,

The amplitudes of the diurnal curve diminish with the latitude, as is very well shown by the following means determined by Angot :—

Mean Amplitudes in mm. of the Diurnal Barometric Oscillation at Continental Stations.

Latitude . . .	20°	28°	41°	45°	46°	49°	54°
a_1	0·75	0·98	0·62	0·36	0·26	0·22	0·15

At stations with maritime situations they are much less. Angot finds for lat. 15°, 0·26; for lat. 39°, 0·15; for lat. 44°-50°, 0·14. In all latitudes we find much greater and also much smaller amplitudes. Irkutsk, in lat. 52° 16′ N., has an annual mean of 0·40 mm., and a summer mean (May–July) of 0·75 mm., while Santiago de Chile, in lat. 33° 27′ S. and at the same altitude, has only 0·15 mm.

The general conditions of the yearly periods of the amplitude and phase time of the diurnal barometric oscillation are best given in Angot's paper (pp. 302-305).

Characteristic Disturbances of the Diurnal Barometric Oscillation on Islands near the Coast.

The results of my calculation of the pressure records from the island of Pelagosa, in the middle of the Adriatic, show very clearly the influence of the daily periodical transfer of masses of air between land and sea, and these are small in winter (in our latitude) and greatest in summer.

Conditions of the Diurnal Barometric Oscillation at Pelagosa.

	Winter.	Spring and Autumn.	Summer.	Year.
Phase time, A_1 . .	24°	275°	288°	291°·5
Amplitude, a_1 . . .	0·044 mm.	0·107 mm.	0·202 mm.	0·100 mm.

In winter A_1 is normal, a_1 very small, clearly owing to the interference of a small pressure oscillation of the same character as that in summer, which is sufficient to reduce but not to obliterate the normal diurnal wave. In the warmer season, however, the local diurnal barometric wave has the upper hand, and delays the flood time from 6.30 a.m. to 11 or 12 o'clock. This is the effect of the mass of air which flows down from high levels on land over the sea (while the sea breeze prevails below).

It has already been explained that ships' observations from the Mediterranean show conditions precisely similar.

The oceanic island of St. Michael (Ponta Delgada), which is large and mountainous, does not show any disturbances of the normal diurnal wave, which are as easily definable as those of the small island of Pelagosa.

Conditions of the Diurnal Barometric Oscillation at Ponta Delgada.

	Winter.	Spring and Autumn.	Summer.
Phase time, A_1 . .	80°	188°	181°
Amplitude, a_1 . .	0·079	0·068	0·049

The change in phase time from winter to summer is quite similar to that at Pelagosa, but the amplitude of the diurnal barometer wave is so small that the change almost entirely disappears.

In Jersey also the diurnal barometric wave is very small (the yearly mean of the amplitude is 0·09 mm.).

In my paper "The Daily Range of the Barometer on Clear and Cloudy Days,"[1] I have shown that the remarkable difference in the daily march of the barometer with differences in weather is entirely due to a modification of the diurnal pressure curve, and that the corresponding differences in this wave have the same character as the differences between the diurnal curve on land and at sea, and that both are probably due to the same causes.

Disturbances on Mountains and Mountain Peaks.

In two papers,[2] I have specially discussed the conditions of the diurnal barometric wave on mountain peaks, and have sought to trace them back to their causes. In my latest paper (January 1898), I have calculated and discussed at length the observations on Pike's Peak (4308 metres) and Mont Blanc (Vallot's Observatory, 4359 metres).

The diurnal barometric wave on mountains and on peaks (extended plateaux behave like low plains) arises from the interference of the diurnal wave, such as we observe at the earth's surface (especially at a place on an extensive plain at the foot of a slope, or on a peak), with the wave which is due to the diurnal periodical variation of temperature in the air stratum which lies below.

We know that the epoch of the daily extremes of the true mean temperature of the air in a stratum of considerable thicknesss is considerably later than the extremes read off from thermometers at an upper and a lower station, as these latter are affected by the influence of the ground beneath them, which is warmed, and is cooled by radiation; and we know further that the daily amplitude of the true air temperature is much less than that resulting from observation. This is clearly shown by the observations on the Eiffel Tower. The newly devised method of observing the temperature of the free air by the use of kites will provide material for studying these conditions more thoroughly. As far as our present knowledge goes, we may assume that the epoch of the daily extremes in a stratum of air of considerable depth (2 kilometres or somewhat more) may be set between 5 a.m. and 5 p.m. If we call the difference between the daily extremes of temperature Δt (*i.e.* the *periodic* daily

[1] *Sitzungsber. der Wiener Akad.* June 1895. *Zeitschrift*, 1896, Littb. p. 4.

[2] *Sitzungsber. der Wiener Akad.* December 1891, "Resultate stündlicher Beobachtungen auf dem Gipfel des Fuji in Japan." *Sitzungsber. der Wiener Akad.* January 1894, "Beiträge zum täglichen Gange der meteorologischen Elemente in den höheren Luftschichten."

amplitude), we have as the expression of the *daily variation in the stratum of air*

$$\tfrac{1}{2}\Delta t \sin (195^\circ + x).$$

This variation of temperature produces at the altitude h, where the barometer is b,—T being the absolute temperature ($t^\circ + 273^\circ$) and R being the well-known gas constant 29·3 (for dry air),—the *thermal pressure oscillation* [1]

$$\tfrac{1}{2}\Delta t\left(\frac{bh}{RT^2}\right) \sin (195^\circ + x).$$

But the diurnal barometric oscillation on the earth's surface has the general form of

$$a_1 \sin (10^\circ + x).$$

At the altitude h, where the barometer reads b, we must put for a_1 $\frac{b}{B}a_1$, where B is the pressure at the lower level. These two oscillations interfere at the altitude h and give us the following diurnal barometric curve:—

Form of the Diurnal Barometric Curve at the Relative Level h.

$$a_1\frac{b}{B} \sin (10^\circ + x) + \tfrac{1}{2}\Delta t\frac{bh}{RT^2} \sin (195^\circ + x).$$

The phases of these two pressure waves are almost exactly opposite. (In mountain valleys and on mountains we often find, instead of $A_1 = 10^\circ$, $A_1 = 15^\circ$ or even more.) We may, without hesitation, put in the first term $A_1 = 15^\circ$, and therefore in the second term $-\sin (15^\circ + x)$, and then we have

Diurnal Barometric Curve at the Level h.

$$\left\{a_1\frac{b}{B} - \tfrac{1}{2}\Delta t\frac{bh}{RT^2}\right\} \sin (15^\circ + x).$$

The amplitude of the diurnal pressure curve always diminishes as we ascend, while the phase time does not change. At a certain relative altitude, where

$$a_1\frac{b}{B} = \tfrac{1}{2}\Delta t\frac{bh}{RT^2},$$

the diurnal wave disappears entirely, but above that level it reappears, but with reversed phase times (A_1 = about 195°), and the amplitudes increase again.

This we actually observe. The relative altitude at which the amplitude of the diurnal curve of the plains quite vanishes lies in general higher in winter than in summer, where the value of Δt is greater.

For the summer I have once determined the following figures:—

	Munich.	Peissenberg.	Wendelstein.	Obir.	Säntis.	Sonnblick.	Mt. Blanc, Vallot Obs.
Relative height (metres)	0	470	1200	1600	2080	2600	3300
A_1 phase time . .	15°	37°	188°	194°	183°	182°	168°
Amplitude (mm.) . .	0·35	0·12	0·08	0·14	0·27	0·32	0·37

[1] *Zeitschrift*, vol. xxvii. 1892, pp. 461, 462. The known hypsometrical formula $\log b = \log B - \frac{h}{RT}$ gives $db = \frac{bh}{RT^2}dt$, if B be constant.

Pike's Peak (relative altitude about 2800 metres) has $A_1 = 210°$ and $a_1 = 0·63$ mm. as its maximum (in spring and autumn), because the daily thermometer range, on the flat and dry tablelands of western North America, is much greater than with us.

We see quite clearly from the little table how the amplitude at first decreases, and then increases again when the phase time changes into its opposite. This increase of amplitude with elevation takes place slowly and has its limits, as we see from the equation stated above, for Δt becomes continually smaller and $\frac{bh}{RT^2}$ is always a proper fraction, which, however, increases with height.

The phase time of the purely thermal pressure wave at the upper level appears to remain very constant, and may be taken on the mean as $A_1 = 190°$. This corresponds to a temperature minimum soon after 5 a.m., and a temperature maximum about 5 p.m. in the stratum lying under the elevated station.

B. *The Semidiurnal Barometric Oscillation.*

The double daily oscillation comes out quite clearly day by day with almost absolutely symmetrical undulations in the tracings of continuous barographs in low latitudes, but in the middle and higher latitudes it is rarely traceable by direct observation, and appears sometimes to be entirely suppressed. It, however, is subject to quite simple laws, and is not affected in either amplitude or phase time by the weather. By the constancy of these elements along each parallel of latitude, and by its regular variation according to season and latitude, it reminds us of the behaviour of cosmical phenomena.

The magnitude of the amplitude of the semidiurnal oscillation seems to decrease with increase of latitude, according to laws similar to those of the theoretical gravitations tide of the ocean. Angot and I have calculated corresponding formulæ of interpolation from the amplitudes observed in different latitudes. Dr. A. Schmidt of Gotha has given the subjoined simple formula for the reduction of the amplitude with the latitude by employing spherical functions.[1]

Variation of the Amplitude (A_2) of the Double Daily Oscillation with the Geographical Latitude (ϕ).

$$A_2 = (0·988 - 0·573 \sin^2 \phi) \cos^2 \phi.$$

This equation gives almost exactly the amplitudes observed on different latitudes up to 65°. The mean values I have given, and which have been used by Dr. Schmidt in his calculations, require some corrections, which can be made out from my paper in the Vienna *Sitzungsberichte* for January 1898. It contains hints as to where disturbances of the amplitude (a_2) are to be looked for, and in what direction these lie, even though no information can possibly be given as to their magnitude. It will, however, be of importance not to use localities where such disturbances are presumed to exist in any calculations of the amplitudes for different parallels of latitude. It will also be necessary for many stations, especially

[1] *Met. Zeitschrift*, vol. xxv. 1890, p. 185.

in the Southern Hemisphere, not only to calculate the harmonic constituents of the daily barometrical fluctuation, but to set up barographs in several localities, well distributed, and also to reduce its records and publish the results. This latter piece of work is usually neglected.[1]

In order to determine more accurately the amount of a_2 at the Equator by the most recent observations, I have made the following calculation, the justification of which will be found in the paper itself:—

Place.	Latitude.	Longitude.	a_2 Observed.	a_2 Reduced.[2]
Cameroons	4° 3′ N.	9° 42′ E.	0·889	0·893
S. Paulo de Loanda . . .	8° 49′ S.	13° 7′ E.	0·865	0·885
Dar-es-Salâm	6° 49′ S.	39° 16′ E.	0·922	0·935
Singapore	1° 15′ N.	103° 51′ E.	0·984	0·984
Batavia	6° 11′ S.	106° 50′ E.	0·950	0·961
Finschhafen (New Guinea) . .	6° 34′ S.	147° 50′ E.	0·890	0·891
Jaluit	5° 55′ N.	169° 40′ E.	0·840	0·849
San José (Costa Rica) . . .	9° 56′ N.	84° 8′ W.	0·918[3]	0·946
Ship observations[4] . . .	4°-10° in	all longitudes	. .	0·925
			Mean .	0·919

This shows us that we must take 0·92 mm. as the most probable value of a_2 at the Equator. Angot has obtained almost the same result. Naturally, the coefficient of $\sin^2 \phi$ in A. Schmidt's formula must be determined afresh.

The yearly period of the magnitude of the amplitude of the semidiurnal oscillation is very remarkable. *It is quite independent of the earth's seasons*, for it is the same in both hemispheres. *The principal maxima occur at the Equinoxes, the principal minimum in June and July, and a second, much smaller, minimum occurs in December and January.*

In both hemispheres, the amplitude or the semidiurnal oscillation is greater at the time of the perihelium than at that of the aphelium. At the epoch of the latter occurs the absolute minimum. This is a cosmical characteristic of the double daily barometrical oscillation.

That the double daily barometric oscillation attains its greatest magnitude from the Equator towards the parallel of 50° when the sun is on the Equator, and not when the sun is in or is nearest to the zenith of the place, is a very important indication of the local origin and the cause of the double pressure oscillation.

[1] In my paper "Weitere Beiträge," quoted above, and in this present paper, there is given some new material for the determination of the variation of a_2 with the latitude.

[2] On the Equator by division with $\cos^2 \phi$.

[3] Reduced with $\frac{B}{b}$.

[4] From the ship's observations near the Equator I take only the following (the observed a_2 are reduced to annual means by using the corrections for the different months given on p. 59):—

Ship.	No of Days.	Latitude. °	a_2 Observed.	a_2 Corrected.	a_2 Reduced.
Novara	35	4·5	·978	·948	·954
Donau	49	5·9	·879	·889	·898
Novara	40	8·0	·995	·927	·946
Novara	40	10·0	·805	·875	·902
			The Mean is	. .	·925

For the tropical stations we get the following equation ($x = 0$ for January):—

Yearly Variation of the Amplitude of the Double Daily Oscillation.

$$0{\cdot}070 \text{ mm. } \sin (96^\circ{\cdot}4 + x) + 0{\cdot}060 \text{ mm. } \sin (293^\circ{\cdot}4 + 2x).$$

In higher latitudes the phase times of this variation remain the same, but the amplitudes are reduced.[1]

From my figures the subjoined corrections have been derived for the amplitudes calculated for individual months (between the Tropics), so as to reduce them to a yearly mean, *i.e.* to the true mean amplitude. These may be possibly found to be of some use.[2]

Corrections of a_2 for a Yearly Mean.

Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
−·014	−·049	−·077	−·048	+·035	+·113	+·125	+·063	−·020	−·063	−0·049	−·016

Local Disturbances of the Magnitude of the Amplitude and of the Phase Time of the Double Daily Oscillation.

These disturbances are small in general, and have not been much investigated. My last paper contains a small contribution on this point under the heading "Daily Barometric Oscillations on Islands"; and another contribution, referring to the influence of the elevation of the stations on hills and mountains, has been given by me before, with an explanation of their causes.

On the coasts, on islands and mountains, the amplitude a_2 is reduced, as compared with its normal value, corresponding to latitude and altitude, and the epochs of the extremes (the tide time) is delayed, especially in summer. Between the Tropics this influence of locality is small, and increases with the latitude, much in the same proportion as a_2 itself is reduced.

The disturbances on mountains are most easily referred to their causes. As the altitude increases the amplitude a_2 should decrease in exact proportion to the pressure (in round terms, in the proportion of $\frac{b}{760}$). This is nearly exactly true, but the observed amplitudes are always somewhat smaller, and, as already remarked, the phase time is delayed (the angle constant A_2 is reduced):

	Latitude.	Altitude.	a_2	A_2
Roorkee	29°·9	287 m.	·800 mm.	145°·4
Simla	31°·1	2280 m.	·537 mm.	138°·5

[1] Angot has attempted to combine the changes in a_2 for latitude and season in one expression. If r represents the radius vector or the sun's distance, δ its declination, ϕ the geographical latitude, we may say:

$$a_2 = 0{\cdot}926 \frac{\cos^2 \delta}{r^2} \cos^4 \phi \sin (154^\circ + 2x).$$

[2] Between the Tropics the total diurnal barometric oscillation, as obtained directly from observation without any resolution into component parts, gives a similar annual curve. If we take the mean ordinate of the diurnal curve of pressure as a measure of the magnitude of the diurnal variation of the barometer (*i.e.* the mean of the deviations of the hourly values from the daily mean, without regard to sign) we obtain:

Yearly Period of the Mean Magnitude of the Observed Diurnal Variation of the Barometer between the Tropics in millimetres.

Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
·58	·62	·64	·64	·58	·54	·54	·57	·60	·62	·61	·59

But Leh, in a valley on the plateau of Thibet, has $a_2 = \cdot 493 A_2 = 154 \cdot 3$, for there is no underlying stratum of air. I have shown how this comes about.

The daily variation of temperature in the stratum of air lying below a mountain station produces, as already explained, a periodical heaving and lowering of the couches of equal pressure above, and thereby an oscillation of pressure, which I have for brevity termed the "thermal pressure oscillation," and which is superposed on the general barometric oscillation at the upper station. In its broad features this thermal pressure oscillation is diurnal, and has been discussed as such. The double daily oscillation is not affected by it. But the daily wave of heat in the underlying station is not symmetrical on both sides of the wave hollow or wave crest, and so it receives a constituent of a semidiurnal period, even though this is a very small one; but this must correspond to a very slight semidiurnal thermal pressure oscillation above. The magnitude of the amplitude of this semidiurnal pressure wave is only about one-tenth of the magnitude of the diurnal curve, and so is only a few hundredths of a millimetre. The double daily barometric oscillation above is therefore not greatly affected, and in a very systematical way, as the following explanation shows.

The form of the semidiurnal portion of the daily thermal variation in the lower air strata is as follows:—

$$+ p'_2 \cos 2x + q'_2 \sin 2x, \textit{ or } a'_2 \sin (A'_2 + 2x);$$

p' and q' are always positive, so that A'_2 lies in the first quadrant: a'_2 only amounts to tenths of a degree (see note 1, p. 49). The corresponding pressure oscillation at the altitude h, where the pressure is b, is obtained by the multiplication of p' and q', or of a'_2, by the quotient $\frac{bh}{RT^2}$, where R and T have the usual signification as in the theory of heat.

But the semidiurnal pressure oscillation is of the form

$$+ p_2 \cos 2x - q_2 \sin 2x, \textit{ or } a_2 \sin (A_2 + 2x)$$

(if p and q are taken as numerical values without signs) A_2 lies always in the second quadrant, and p is always less than q. The resulting pressure oscillation above is obtained by addition of these two equations.[1]

From this we see clearly that the superposition of the first (the thermal) pressure wave on the normal double daily oscillation of the barometer at a high-level station consists in this, that p_2 is increased (p'_2 and p_2 have the same sign), and q_2 is reduced (q'_2 and q_2 have opposite signs); and so the values of p and q approach each other. The resulting angle $\frac{p_2}{-q_2} = -v_2$ is therefore increased, and the constant angle A_2 (*i.e.* $180° - v_2$) is reduced. The phase angle above is somewhat delayed. The proportion in which a_2 is reduced, or if it is reduced at

[1] It may be shown how the phase angle A is obtained from p and q. We had before:

$$p_2 \cos 2x + q_2 \sin 2x, \textit{ or } a_2 \sin (A_2 + 2x).$$

$a_2 \sin (A_2 + 2x)$ is equal to $a_2 \sin A_2 \cos 2x + a_2 \cos A_2 \sin 2x$. In order to make the two equations identical, we must put $p_2 = a_2 \sin A_2$, and $q_2 = a_2 \cos A_2$. Thence we have $\frac{\sin A_2}{\cos a_2} = \tan A_2 = \frac{p_2}{q_2}$. The phase angle A_2 is therefore derived from the quotient of $\frac{p}{q}$. At the same time we may remark that $a_2 = \frac{p_2}{\sin A_2}$. or $= \frac{q_2}{\cos A_2}$. So p, q, a, and A are all connected together.

all, depends on the magnitudes of p'_2 and q'_2; but as p_2 is increased, and the divisor sin v_2 is also increased, so the change in a_2 is in general very small. The amplitudes of the *semidiurnal* thermal pressure wave are only fractions (usually not more than a tenth) of the normal semidiurnal barometric oscillation at the respective heights. For example :—

Influence of the Thermic Dilatation of the Underlying Air Stratum on the Semidiurnal Oscillation of Pressure at the Eiffel Tower.

Semidiurnal Oscillation of the Barometer (Summer 1890).

	h	p_2	q_2	a_2	A_2
Paris (Bureau Cent. Mét.) .	33·4 m.	+·154	−·228	·275	146°·0
Eiffel Tower	312·9 m.	+·181	−·197	·267	137°·4

The difference in $A_2 = 8°\cdot6 = 17$ minutes retardation of the tropical hours on the Tower.

Daily Variation of Temperature between Paris and the Eiffel Tower (Summer 1890).

p_2	q_2	a_2	A_2
+0°·34 C.	+0°·15 C.	0°·37 C.	66·2

This gives as the thermic oscillation of pressure at the Eiffel Tower the factor for reduction [1] $\frac{bh}{RT^2} = 0\cdot088$, so

	p_2	q_2
Thermic pressure oscillation at the Eiffel Tower	+0·030	+0·013
Eiffel Tower observed	+0·181	−0·197
Thermic oscillation subtracted—		
Eiffel Tower (corrected)	+0·151	−0·210
Paris Bureau Central	+0·154	−0·228

Very nearly in accordance.

The corrected A_2 at the Eiffel Tower is therefore $\frac{p_2}{q_2} = \tan A_2$, $A_2 = 144°\cdot3$; at Paris $= 146°\cdot0$. Difference only $1°\cdot7 = 3$ minutes time of phase, and $a_2 = 0\cdot259$, nearly unaltered.

If it were possible (which unfortunately it is not) to determine by means of our thermometer readings the true temperature range of the stratum of air lying under an elevated station, we should be able to calculate accurately the influence of the temperature range on the daily barometric oscillation, and thereby to correct the latter. In general, however, the observations give the amplitude of the daily variation of temperature too high and the phase epoch too early.

The influence of the land and sea breezes, *i.e.* of the periodical transfer of air from land to sea, and *vice versa*, in the daily period has a very similar influence on the double daily barometric oscillation on coasts and islands (as will be seen from what follows), as that of the periodical upheaval of the couches of equal pressure has on the barometric oscillation at the upper stations. The amplitude a_2 is reduced (frequently to a great extent) and the phase time is delayed (the angle constant A_2 is pushed back towards the first quadrant). The periodical transfer of the masses

[1] $b = 733\cdot5$; $h = 279\cdot5$; $R = \frac{p_0 v_0}{T_0} = 30\cdot4$; a (coefficient of dilatation regarding the humidity) $= 0\cdot0038$. T_0 therefore $= 263$; and $T_0 + t = 263 + 14 = 277°$ C.

of air from the land to the sea appears therefore (although of course this has mainly a diurnal period) to have a small constituent part with a semidiurnal period, which has a similar form to that above proved to exist for the action of the thermal pressure wave at mountain stations.

If we were able to establish more precisely the normal conditions of the barometrical oscillation for the respective coast and island stations, we should be able to calculate more accurately the periodical transfer of air which is the cause of the land and sea breezes.

On the other hand, it appears that in the middle latitudes there, where in mountain valleys (Botzen, Klagenfurt, Death Valley in California, etc.) the diurnal barometric wave has an extraordinary magnitude, the amplitude of the semidiurnal wave is also somewhat increased, but the phase time is very little changed. More thorough investigation is, however, required to establish this as a fact. If this should ever be proved, we must assume that the periodical transfer of air, which is the cause of the mountain and valley winds, has also a small component of semidiurnal period; but this will have a form somewhat different from that above mentioned.

The mean phase time of the double daily oscillation in the equation $a_2 \sin (A_2 + 2x)$ is given by the phase angle $A_2 = 155°$ (Angot takes 154°), the time being reckoned from midnight. This corresponds to an epoch for the first tide at 9.50 a.m. In higher latitudes the tide seems to be a little later: the mean value for 50° N. is about 147° (a delay of about $\frac{1}{4}$ hour). There are, however, many local and systematical variations which have not yet been investigated.

I have investigated the yearly period of the double daily oscillation in my first paper (vol. lv. of the *Denkschriften*, p. 90). In both hemispheres the hours of change are somewhat earlier in winter and somewhat later in summer.

C. *The Tri-daily Oscillation of the Barometer.*

If we resolve the complex phenomenon of the daily barometric oscillation into its harmonic constituents, and go on to the third term of the variable angle, we find that these constituents have now a very small amplitude, of which the magnitude lies between 0·02 and 0·05 mm. in the yearly mean, while the phase time is fixed by the constant angle 350° to 360°. It has therefore the following general form:—

$$0{\cdot}04 \text{ mm. } \sin (355° + 3x).$$

The constant angle A_3 is nearly similar at all stations, and the amplitude a_3 decreases slightly with the latitude.[1]

The most remarkable phenomenon of the tri-daily barometric oscillation (with the period of 8 hours) is the decided and generally quite uniform yearly period of the amplitude a_3, and of the phase time A_3, which is specially remarkable in view of the slight magnitude of these constituents.

The reason of this is that hardly any meteorological phenomenon exists with a decided 8-hour period, so that the 8-hour barometric oscillation is almost undisturbed, despite its slight amplitude.

The maxima of the magnitude of the amplitude a_3 in both hemispheres fall in winter (principal) and summer, the minima at the equinoxes.

[1] In my paper "Untersuchungen über die tägliche Oscillation des Barometers" (Vienna, 1889), and also in Angot's paper already cited, the values a_3 and A_3 have been calculated for several stations.

Cole points out that at all stations the phase time is reversed at the equinox, and this explains the existence of the minima at the same period.

The third harmonic constituent of the diurnal barometric oscillation is therefore a very important component of the diurnal barometric oscillation, owing to its universally constant character.[1]

* * * * * *

Inasmuch as the paper of which I have given in the foregoing an abbreviated reproduction had as its subject the discussion of barometric observations taken on the open sea, I shall give here as an extract some of these results of calculation, but I must refer to the original paper for the details of the deduction of these mean results (especially as to locality and season). There full information will be found.

DAILY OSCILLATION OF THE BAROMETER ON THE OPEN SEA.

Results of Observations taken on board the "Novara," 1857-59.

	Equatorial Pacific.		Equatorial Indian Ocean.	Indian Ocean in locality of Nicobar Is'nds.[2]	Pacific Ocean in locality of Guam-Puinipet.	North Atlantic Ocean.	Pacific Ocean.	Pacific Ocean (West)	Pacific Ocean (East).	North Atlantic Ocean.	Mediterranean.
Latitude	6°	3°·8	5°	8° N.	10°·7	10°N.	16½° S.	34° S.	33° S.	37½°N.	37½°N.
No. of days	40	20	15	40	20	20	40	34	30	20	30
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Midnight	·34	·35	·49	·20	·27	·60	·39	·07	·06	·20	-·09
1 A.M.	-·04	·04	·23	·07	-·14	·06	-·03	-·41	-·14	·05	-·18
2 ,,	-·45	-·34	-·21	-·44	-·39	-·19	-·30	-·68	-·27	-·55	-·23
3 ,,	-·77	-·64	-·59	-·88	-·71	-·49	-·59	-·76	-·49	-·55	-·32
4 ,,	-·81	-·73	-·75	-·77	-·72	-·61	-·56	-·71	-·57	-·69	-·41
5 ,,	-·49	-·42	-·50	-·52	-·34	-·58	-·30	-·36	-·43	-·41	-·34
6 ,,	-·08	-·02	-·07	-·15	-·03	-·34	·06	·00	-·10	-·35	-·13
7 ,,	·45	·51	·52	·39	·54	·18	·40	·29	·20	-·14	-·02
8 ,,	·96	1·03	·85	·94	·88	·35	·84	·50	·48	-·09	·18
9 ,,	1·18	1·24	·92	1·38	1·09	·49	·99	·62	·65	·18	·50
10 ,,	1·13	1·18	·96	1·45	1·01	·54	·91	·64	·74	·36	·63
11 ,,	·84	·83	·75	1·17	·69	·65	·59	·50	·60	·26	·61
Noon	·35	·26	·20	·58	·30	·20	·21	·37	·36	·17	·61
1 P.M.	-·34	-·40	-·37	-·05	-·34	-·06	-·32	·19	·06	·25	·50
2 ,,	-·94	-1·02	-·97	-·60	-·75	-·55	-·74	·04	-·29	·05	·36
3 ,,	-1·17	-1·28	-1·18	-1·03	-1·09	-·77	-1·00	-·15	-·49	-·32	·02
4 ,,	-1·20	-1·33	-1·27	-1·19	-·94	-·79	-1·03	-·31	-·50	-·20	-·16
5 ,,	-·94	-1·05	-·84	-·99	-·75	-·66	-·88	-·35	-·42	-·04	-·34
6 ,,	-·57	-·63	-·48	-·74	-·54	-·52	-·58	-·24	-·31	-·10	-·43
7 ,,	-·07	-·18	-·19	-·34	-·08	-·07	-·17	-·01	-·07	·10	-·29
8 ,,	·35	·22	·31	·10	·21	·29	·19	·04	·17	·45	-·18
9 ,,	·65	·76	·70	·45	·48	·61	·57	·27	·27	·67	-·11
10 ,,	·87	·92	·87	·65	·70	·85	·74	·24	·32	·45	·04
11 ,,	·72	·72	·72	·47	·56	·81	·64	·19	·17	·25	·00
Mean . .	·66	·67	·61	·65	·56	·47	·54	·33	·34	·29	·28
Pressure[3]	759·4	759·3	760·6	759·7	759·1	758·9	760·5	760·0	763·4	765·3	759·4

[1] See my paper above quoted (p. 91); and Angot, *Étude sur la marche diurne du baromètre*, pp. 325-336; and Cole, "The Diurnal Variation of Barometrical Pressure," *U.S. Weather Bureau*, Bulletin No. 6, 1892; or *Met. Zeitschrift*, 1894, p. 23.

[2] Between the islands the amplitude of the diurnal range is probably augmented, but the diurnal barometric range over the whole area of the Indian monsoons is abnormally great.

[3] Without correction for gravity. Altitude, 3 metres.

	Zrinyi. 1885-86.	*Saida.* 1890-91.				*Donau.* 1895.				*Aurora*[1] 1895-96.
Latitude	33°·8 N.	4°	13°	26°	35°	5°·9	22°·7	35°·7	39½°	10½°
No. of days	24	26	29	14	50	49	68	23	34	38
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Midnight	·16	·30	·29	·37	·23	·57	·35	·10	−·12	·11
1 A.M.	·02	·04	·10	·28	·12	·00	·03	−·09	−·31	−·24
2 ,,	−·26	−·36	−·23	·04	−·08	−·42	−·27	−·24	−·42	−·55
3 ,,	−·50	−·58*	−·42	−·27	−·23	−·66	−·46	−·39	−·45*	−·73*
4 ,,	−·58*	−·56	−·48*	−·43*	−·31*	−·72*	−·54*	−·47*	−·41	−·66
5 ,,	−·31	−·33	−·32	−·43	−·20	−·52	−·45	−·42	−·28	−·36
6 ,,	−·10	−·04	−·04	−·22	−·05	−·25	−·21	−·25	−·11	·08
7 ,,	·15	·44	·40	·14	·15	·16	·11	−·07	·07	·70
8 ,,	·42	·82	·72	·30	·26	·53	·40	·09	·17	1·18
9 ,,	·60	1·02	·91	·53	·37	·82	·61	·26	·28	1·51
10 ,,	·68	1·05	·95	·61	·38	·92	·72	·29	·30	1·42
11 ,,	·46	·81	·73	·49	·28	·83	·62	·16	·24	1·05
Noon	·22	·26	·34	·18	·09	·48	·35	·05	·16	·45
1 P.M.	−·30	−·34	−·26	−·23	−·15	·00	−·02	−·10	·05	−·34
2 ,,	−·58	−·86	−·71	−·56	−·41	−·51	−·34	−·28	−·06	−·84
3 ,,	−·64*	−1·06	−1·02	−·77	−·49	−·89	−·57	−·29	−·13	−1·19
4 ,,	−·64*	−1·07*	−1·09*	−·80*	−·53*	−·97*	−·66*	−·30*	−·16*	−1·23*
5 ,,	−·39	−·86	−·87	−·60	−·42	−·88	−·63	−·22	−·14	−1·03
6 ,,	−·17	−·50	−·52	−·36	−·25	−·57	−·50	−·04	−·03	−·70
7 ,,	·13	−·11	−·23	·12	−·05	−·17	−·19	·30	·12	−·22
8 ,,	·40	·17	·16	·28	·15	·23	·01	·53	·32	·16
9 ,,	·47	·54	·46	·48	·34	·56	·43	·55	·38	·47
10 ,,	·50	·72	·59	·52	·40	·73	·57	·46	·30	·54
11 ,,	·38	·58	·51	·50	·35	·78	·54	·31	·15	·41
Mean. .	·38	·56	·51	·39	·26	·55	·39	·26	·21	·67

I extract from the text to the tables (which are given more fully in the original) the following sentences:—

During the scientific circumnavigation of the *Novara*, observations of all the meteorological elements were taken in part two-hourly (with addition of the hours of 9 a.m. and 3 p.m., so as to catch the turning hours of the barometer), and in part (the major part) hourly. These observations are published in full in the work: B. v. Wüllerstorf-Urbair, *Reise der österreichischen Fregatte "Novara" um die Erde in den Jahren* 1857-59. *Nautisch-physikalischer Theil, herausgegeben von der Hydrographischen Anstalt der k. k. Marine* (Wien, 1862-65).

This book is of extreme value for the meteorology of the ocean. It is almost unique in its character, and allows of the deduction of the daily range of all the elements over the open sea; but it has hardly ever been utilised for this object, although it offers special advantages for that object, as the *Novara* was a sailing ship and therefore gives us more trustworthy records of the direction and force of the wind.

Example.—*The Equatorial Pacific*, in the strict sense, mean lat. 3°·8, September 19 to October 8, 1857, from Puinipet to the Solomon Islands. From Puinipet the course of the *Novara* was directly southerly, but the sailing ship got into the doldrums so that she made very little way, and that induced me to work up these observations very specially, as they refer to very narrow limits of latitude and longitude. From 6° N. to 8° S. latitude the ship took 20 days, and was always between

[1] Arabian Sea and Bay of Bengal; time of the North-east Monsoon; dry and clear.

160° and 162° E. longitude. (The five days' positions from September 19 to October 8 inclusive were as follows: 4°·8 N., 160° E.; 2°·1 N., 161°·4 E.; 2°·2 S., 160°·8 E.; 6°·0 S., 160°·7 E.)

Hochstetter writes about this trip[1]: "We made very little way; to-day we caught the sun so that at noon it stood north of us, but after a few days it caught us up, and we saw it south of us. The heat was oppressive; in vain we looked for shelter. Rain poured down in torrents, often for 12 hours on end, and the clouds were so dense that daylight could only pierce them dimly, and these were the chief enjoyments of the trip. We should have gladly welcomed the heaviest storm if it would only have taken us out of this horrible zone." The log gives rain on 17 days out of 20. Accordingly, the barometer range for this period is that of true doldrum weather, and is therefore specially interesting. It is, as will be seen, just the same in the doldrums as outside it. The five-day means I got out agree exactly *inter se.* The mean position is lat. 3°·8 S., long. 160°·8 E.

TYPICAL MEAN VALUES FOR THE DIURNAL BAROMETRIC OSCILLATION ON OPEN SEA, FROM THE *NOVARA* OBSERVATIONS.

Latitude . No. of days	4½° 35	10° 40	33½° 64	Latitude . No. of days	4½° 35	10° 40	33½° 64
	mm.	mm.	mm.		mm.	mm.	mm.
Midnight .	·42	·38	·07	Noon .	·23	·27	·39
1 A.M. .	·13	−·07	−·27	1 P.M. .	−·38	−·25	·13
2 ,, .	−·27	−·32	−·48	2 ,, .	−1·00	−·68	−·13
3 ,, .	−·62	−·64	−·62	3 ,, .	−1·23	−·98*	−·32
4 ,, .	−·74*	−·68*	−·64*	4 ,, .	−1·30*	−·89	−·40*
5 ,, .	−·46	−·42	−·40	5 ,, .	−·94	−·72	−·39
6 ,, .	−·05	−·13	−·05	6 ,, .	−·55	−·53	−·27
7 ,, .	·51	·42	·24	7 ,, .	−·18	−·08	−·04
8 ,, .	·94	·70	·49	8 ,, .	·27	·24	·10
9 ,, .	1·08	·89	·64	9 ,, .	·73	·52	·27
10 ,, .	1·07	·85	·69	10 ,, .	·89	·75	·28
11 ,, .	·79	·68	·55	11 ,, .	·72	·64	·18

The morning minimum remains almost unchanged, but as the latitude increases the maximum decreases both in morning and evening, especially the latter, as does also the afternoon minimum.

Lieutenant (now Commander) Sobieczky, to whom we owe the records of hourly and two-hourly observations on several trips to the West Indies and back, on board the *Zrinyi*, made hourly observations of wind force (Beaufort scale) in the North Atlantic Trade Wind region between lat. 24° and 15°, and long. 24° and 49° W. between October 15 and November 5, 1885, and these are of great interest.

These give us two maxima, at 8 a.m. and 9 p.m., and two minima, at 3 a.m. and 3-4 p.m.; these agreeing almost exactly with the barometric wave. The equation of the daily range of wind force is:

Diurnal Variation of Wind Force in the Tropical North Atlantic Ocean.

$$2{\cdot}68 + 0{\cdot}065 \sin (6^\circ{\cdot}1 + x) + 0{\cdot}216 \sin (181^\circ{\cdot}3 + 2x).$$

Accordingly, the tropical hours of the double diurnal oscillation come not quite an hour earlier than in the case of pressure.

[1] F. v. Hochstetter, *Gesammelte Reiseberichte*, 1857-59 (Vienna: Hölzel, 1885), p. 290.

PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

November 16, 1898.

Ordinary Meeting.

Francis Campbell Bayard, LL.M., President, in the Chair.

Isaac Jackson Brown, 2 St. Thomas Street, Weymouth ;

James Edmund Clark, B.A., B.Sc., F.G.S., 24 Birdhurst Road, South Croydon ;

Thomas Walker Fowler, F.R.G.S., F.G.S., University, Melbourne ;

Charles Kelly, M.D., F.R.C.P., Ellesmere, Gratwicke Road, Worthing ; and

Capt. Joseph Walter Cook Martyr, 14 Curtyvil Road, Penarth, Cardiff,

were balloted for and duly elected Fellows of the Society.

The President stated that in consequence of notice having been served on the Society by H.M. Office of Works for the acquisition of the rooms at No. 22 Great George Street, the Council had taken a suite of rooms on the second floor at Princes Mansions, No. 70 Victoria Street, on lease for twenty-one years.

Mr. A. Brewin and Mr. J. K. Laughton, on behalf of the Fellows, expressed their thanks to the Council for the action they had taken in the matter.

It was announced that the change of address would take place on January 1, 1899.

The following communications were read :—

"Report on Experiments upon the Exposure of Anemometers at Different Elevations." By The Wind Force Committee (p. 1).

"Comparison of Estimated Wind-Force with that given by Instruments." By Capt. D. Wilson-Barker, F.R.S.E., F.R.Met.Soc. (p. 13).

"The Tornado at Camberwell, October 29, 1898." By William Marriott, F.R.Met.Soc. (p. 19).

December 21, 1898.

Ordinary Meeting.

Francis Campbell Bayard, LL.M., President, in the Chair.

John Alfred Curtis, 20 Barclay Road, Fulham, S.W. ;

John Dickinson Leigh, M.B., 7 Avenue Road, Scarborough ; and

Harry Bertram Nichols, Assoc.M.Inst.C.E., 59 Corporation Street, Birmingham,

were balloted for and duly elected Fellows of the Society.

Mr. F. Gaster and Mr. M. Jackson were appointed Auditors of the Society's Accounts.

The following communications were read :—

"THE WEST INDIAN HURRICANE, SEPTEMBER 1898." By Capt. A. CARPENTER, R.N., D.S.O., F.R.Met.Soc. (p. 23).

"THE CONNECTION BETWEEN THE WINTER TEMPERATURE AND THE HEIGHT OF THE BAROMETER IN NORTH-WESTERN EUROPE." By W. H. DINES, B.A., F.R.Met.Soc. (p. 32).

CORRESPONDENCE AND NOTES.

Temperature of the Air at Jerusalem.—In the *Quarterly Statement* of the Palestine Exploration Fund for July 1898, Mr. James Glaisher, F.R.S., gives a paper on the temperature of the air at Jerusalem, based on continuous observations during the 15 years 1882-96. Observations had been made by Dr. T. Chaplin from 1861 to 1881, but from 1882 the observations have been made under the superintendence of the Palestine Exploration Fund, and it is the latter which Mr. Glaisher has discussed in the above paper. The results of Dr. Chaplin's observations were published in the *Journal of the Scottish Meteorological Society*, March 1882, and in the *Quarterly Statement* of the Palestine Exploration Fund, January 1883.

Jerusalem is situated in lat. 31° 46′ 40″ N., and long. 35° 13′ 30″ E., and is about 2500 feet above the level of the Mediterranean Sea.

The annual mean temperature of the 15 years was 62°·3. August is the warmest month of the year, the mean temperature being 76°·6; and January the coldest month, the mean temperature being 44°·6.

The highest temperature recorded during the 15 years was 108° on June 18, 1894, the next highest being 106° on July 12 and 13, 1888. The highest temperature recorded by Dr. Chaplin was 112° on August 28 and 30, 1881. During the 15 years 1882-96 the temperature exceeded 100° on 28 days, and was above 90° on 581 days.

The lowest temperature was 26°·5 on January 26, 1890. The temperature fell to, or below, 32° in every year excepting 1885 and 1892.

Mean Temperature of the Air at Jerusalem, 1882-96.

Year.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Mean.
	°	°	°	°	°	°	°	°	°	°	°	°	°
1882	43·6	42·5	54·4	60·8	64·7	71·7	74·5	76·8	76·0	66·3	59·7	52·9	62·0
1883	47·2	46·1	54·9	59·8	66·7	73·4	74·9	76·1	74·8	67·0	58·0	49·1	62·3
1884	43·7	44·2	51·7	63·3	66·3	73·9	73·7	75·8	69·3	67·9	56·8	52·3	61·6
1885	45·5	49·5	55·4	57·5	71·4	71·7	74·1	75·8	73·4	69·3	60·0	50·7	63·0
1886	46·5	47·9	49·5	57·6	63·6	74·1	72·6	75·3	72·3	66·8	53·4	47·0	60·5
1887	42·5	47·8	52·2	62·8	64·6	73·0	75·5	76·8	72·3	74·7	58·6	47·2	62·3
1888	43·4	50·7	58·5	61·0	65·1	72·0	81·1	77·2	75·0	73·1	51·4	47·9	63·0
1889	46·2	49·4	57·9	61·2	69·5	73·9	78·2	77·5	72·6	70·7	54·2	46·9	63·2
1890	39·8	45·5	55·7	61·0	69·2	74·2	80·0	81·2	72·8	69·9	60·0	49·3	63·2
1891	45·9	44·4	52·7	62·4	69·5	73·4	76·4	78·2	73·6	69·3	59·3	49·9	62·9
1892	46·8	50·0	54·7	62·3	67·7	72·9	74·7	75·8	77·0	72·0	57·5	50·2	63·5
1893	46·5	46·3	51·1	55·8	66·2	75·4	79·3	74·0	70·7	65·9	60·7	47·5	61·7
1894	42·3	44·3	50·6	55·1	66·7	73·4	73·7	72·8	71·0	69·4	54·1	46·2	60·0
1895	45·0	50·2	50·7	61·2	69·0	70·8	76·3	75·5	71·2	63·9	56·2	51·5	61·8
1896	43·8	45·3	50·1	57·8	67·2	71·9	76·0	80·4	74·0	72·0	60·8	55·5	62·9
Monthly Mean	44·6	46·9	53·3	60·0	67·2	73·0	76·1	76·6	73.1	69·3	57·4	49·7	62·3

Extreme Temperature of the Air at Jerusalem, 1882-96.

	Maximum.			Minimum.		
Month.	Mean.	Extreme.	Year.	Mean.	Extreme.	Year.
	°	°		°	°	
January .	51·0	65·5	1893	38·2	26·5	1890
February .	54·1	73·5	1887	39·7	28·0	1893, 1894
March . .	62·5	90·5	1888	44·2	28·5	1886
April . .	69·8	94·8	1889	50·2	30·0	1886
May . .	78·4	97·0	1889	56·0	38·5	1887
June . .	84·7	108·0	1894	61·3	48·5	1882
July . .	87·8	106·0	1888	64·3	51·0	1894
August .	89·3	105·0	1884	63·9	52·5	1886
September	85·3	101·0	1892	60·8	50·0	1895
October .	80·6	96·5	1883	58·2	41·5	1886
November	65·9	86·0	1895	48·9	34·0	1889
December.	56·7	72·0	1896	42·6	27·5	1893

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THE GOVERNMENT METEOROLOGICAL ORGANISATIONS IN VARIOUS PARTS OF THE WORLD.

BY F. CAMPBELL BAYARD, LL.M., PRESIDENT.

An Address delivered to the Royal Meteorological Society, January 18, 1899.

IT is a pleasure to me, as well as my duty, to come before you to-night and deliver the Annual Presidential Address. Presidents come and go, but this Society, we all hope, will long outlive them. The Society, perhaps rightly, gives a free hand to its President, enabling him to address you on subjects which may not be strictly Meteorological, though near akin to the branch of science to which we belong. In the year 1885, Dr. Scott, our estimable Foreign Secretary, when President, delivered an address on "The Climatology of the Globe," in which he enumerated all, or nearly all, of the second order stations at which meteorological observations were then taken. This evening I propose to continue this work, and to place before you some brief particulars of "The Government Meteorological Organisations in Various Parts of the World," with which the stations mentioned by Dr. Scott, or the majority of them, were then, or are now, affiliated.

With this object, I drafted the following letter, which was sent out from the Society's office by Mr. Marriott; and in reading this letter to you, I ask you to bear in mind its terms, which show the scope of the inquiry. The letter is as follows:—

Dear Sir,—The PRESIDENT (Mr. F. Campbell Bayard) proposes, in his Address to this Society, in January next, to take the subject of the various meteorological organisations.

In order to prepare this and make it as accurate and serviceable as possible, he would be glad if you would kindly furnish him with some particulars about the organisation in your country. The points upon which he wishes information are as follows:—

1. A short historical account of the meteorological organisation, showing its foundation, its scope, and the names of its chiefs.
2. The present state of the organisation, showing the number and descriptions of its stations: first order, second order, etc.
3. If weather-forecasting has been undertaken, what has been the percentage of success?
4. A short list of any completed investigations.
5. A short list of any investigations now in progress.
6. The amount of grant from Government. (This is asked for in order to show the amount voted by the different States towards the support of Meteorological Science.)

A reply as early as convenient would be esteemed a favour.

Could you also kindly send a photograph of yourself, and of one of your principal stations, so that lantern slides may be made of them, and shown on the screen when the Address is delivered.

This letter was sent out to the Directors of the various meteorological organisations by Mr. Marriott at various times, commencing with June 30, 1898; and it is a pleasure to me, at the commencement of this Address, to acknowledge the very efficient help that I have received from our Assistant-Secretary: he has made lantern slides of the photographs sent, and has aided me in ways too numerous to mention.

Many of the replies, and the books referred to in them, were in various languages, and I have had to ask the help of one of our Fellows, Mr. J. S. Harding, in translating them. This aid he has most cordially given, and I wish to tender him my thanks for the great service he has rendered to me.

The replies to my circular letter have been most gratifying. Fifty-one letters were sent out, and a very courteous response has, with one exception, been made to my request.

I propose now to summarise very shortly the replies which are given in the Appendix (p. 87), and in doing so I wish to acknowledge my indebtedness to the *Report of the Meeting of the International Meteorological Committee at Copenhagen* in 1882, and the different summaries on European Meteorological Organisations published in *Symons's Meteorological Magazine* for 1881. These two publications have enabled me to clear up many points which would otherwise have been obscure.

No report having come in from New Zealand, I am indebted to Sir Charles Todd's paper, "Meteorological Work in Australia: a Review," presented by him to the Society in 1894, for the few words I have been able to put together.

EUROPE.

Austro-Hungarian Empire.

The Central Anstalt for Meteorology and Terrestrial Magnetism at Vienna was established in 1851, and the present Director is Prof. J. M. Pernter, who was appointed in 1897. The duties of the Central Office relate to the reduction and discussion of the observations of the Central Office and the different stations, weather service and forecasting, and the reduction and discussion of the magnetic observations. The stations number 506, of which 25 are first order, 175 second order, 230 third order, and 76 fourth order. No list of the finished investigations,

which have been very numerous, is given, and at the present moment there is no special investigation in progress. The total expenses are, in English money, £2876, which is provided by the Government. (I. p. 87.)

The Meteorological and Magnetic Observatory at Pola is a marine observatory attached to the Hydrographic Office of the Navy, of which it forms the Fifth Division (Geophysics). The present Director of the Hydrographic Office is Rear-Admiral A. von Kalmár,[1] and the Director of the Observatory Lieut. W. Kesslitz. There are 2 second order stations and 3 rainfall stations attached to the Observatory. The vote for the fifth division is about £125, exclusive of the cost of publications and printing. (II. p. 88.)

Until 1870, the Hungarian Weather Service formed part of that of Austria, but on April 8 of that year it was formed into a separate system with an office at Buda-Pesth, under the direction of Prof. Schenzl. The present Director is Dr. N. von Konkoly. The number of stations attached to the Office is about 351, of which one is of the first order and the remainder of the second and third orders. The Agricultural Society of the Valley of Neutra has a number of stations of the second and third orders, and has since 1879 issued weather forecasts based on the résumés from Vienna. A daily weather report is published by the Hungarian Central Office, but I do not know whether or not forecasts are issued. With respect to the published works, all the old Hungarian observations up to 1865 have been discussed. No special investigations seem to be in progress. The expense to the Government of the service is about £1910.

Belgium.

The Royal Observatory of Brussels, now situated at Uccle, was founded in 1826 by Quetelet, but did not commence regular work till 1833. From the first, Meteorology occupied a large place. A certain number of stations was established in 1845 in Agricultural Schools and in the Civil and Military Hospitals, but these gradually came to an end, so that at Quetelet's death in 1874 only 4 remained. In 1876 Mons. Houzeau was appointed, to be succeeded in 1885 by Mons. Folie, and later on by the present Director, Mons. A. Lancaster. All these three gentlemen warmly took up the subject of Meteorology, with the result that there are now about 72 climatological stations and 250 rainfall stations attached to the Royal Observatory. Storm warnings are issued and forecasting is undertaken, but no percentage of success is given. Numerous publications relating to the climate of Belgium have been issued. The vote for Meteorology in 1897 amounted to about £2000. (III. p. 89.)

British Isles.

The Meteorological Department of the Board of Trade was established in 1854, with Admiral Fitz-Roy as its chief. After the death of Admiral Fitz-Roy in 1867, the Government placed the Office under the management of a Committee of the Royal Society, with Sir Edward Sabine as Chairman and Mr. R. H. Scott as Director. In 1877 the Office was reconstituted, and placed under the management of the

[1] Replaced, May 1, 1899, by Captain von Pott.—Editors.

Meteorological Council, the present Chairman of which is Lieut.-General Sir Richard Strachey, and the Secretary Mr. R. H. Scott. The duties of the Office relate to Marine Meteorology, Weather Telegraphy, and Land Meteorology. The stations attached to the Office number altogether 269, which are divided into 7 categories, viz. (*a*) Observatories 7, (*b*) Anemographic 15, (*c*) Barographic 15, (*d*) Sunshine 62, (*e*) Telegraphic 30, (*f*) second order 79, and (*g*) third order 61. Forecasting is undertaken, the percentage for forecasts for the 10 years 1887-96 being 81·6, and for storm warnings for the same period 87·3.

The publications are very numerous, and are divided into "official" and "non-official."

The Government grant is £15,300 and free printing. (IV. p. 89.)

DENMARK.

The Danish Meteorological Institute was founded at Copenhagen in April 1872. It is divided into five departments: (1) Climatology, (2) Weather Service, (3) Nautical Service, (4) Mareographic Observations, and (5) Magnetical Observations. The present Director is Dr. Adam Paulsen. There are 282 stations attached to the Institute, divided into (1) first order 1, (2) second order 24, (3) stations with thermometer and rain-gauge 150, (4) stations with rain-gauge 107. Thirty-one of these stations are in the colonies of Faroe, Iceland, and Greenland, and there is besides 1 second order station in the West Indies. Weather forecasting is undertaken, and the percentage of success is 82. A long list of completed investigations is given. The amount of the Government grant is £4300. (V. p. 91.)

FRANCE.

The Meteorological Service of France was established in 1855 by Le Verrier, and was a special branch of the Observatory of Paris. After his death in September 1877, it was constituted a separate service, under the name of The Central Meteorological Office of France, by a decree of May 14, 1878. Prof. E. Mascart is now the Director. The stations attached to the Office number 2236, and comprise 12 of the first order, 5 mountain stations, 183 of the second order, and 2036 of the third order, including rainfall stations. Forecasts are issued, and for 1897 a large percentage of success, viz. 91, was claimed. Numerous investigations have been undertaken. The expense of the service is about £7300, but this amount is exclusive of allowances for the mountain stations of Pic-du-Midi and Puy-de-Dôme. (VI. p. 91.)

GERMAN EMPIRE.

Hamburg.—The Deutsche Seewarte at Hamburg was founded in January 1875, and amalgamated with the Nord-deutsche Seewarte, which had been founded in 1867. The present Director is Dr. G. Neumayer. It is the imperial system of the Empire, but it works in harmony with the meteorological systems of (1) Prussia, (2) Bavaria, (3) Saxony, (4) Würtemberg, (5) Baden, and (6) Alsace-Lorraine. It controls and manages maritime meteorology, storm warnings, and forecasts. There are between 160 and 170 stations attached to the system, of which 30

are of the second or third order. The percentage of successes in forecasting does not seem to have been calculated. Numerous investigations have been undertaken. No particulars as to the Government grant are given. (VII. p. 91.)

Prussia.—The Royal Prussian Meteorological Institute was established, at the instigation of Baron A. von Humboldt, by a Cabinet decree of October 17, 1847, in connection with the Royal Statistical Bureau. On April 1, 1886, it became an independent institution under the Prussian Minister of Worship. The present Director is Dr. W. von Bezold. The non-Prussian States of North Germany, such as Mecklenburg, Oldenburg, etc., have, with their stations, joined the Institute, and the number of stations connected with it is 3582, of which 122 are of the first and second order, 60 of the third order, 2000 rain-gauge stations, and 1400 thunderstorm ones. Weather forecasts are not issued. Numerous investigations have been finished and published, and 4 special ones are in hand. The annual budget of the Institute amounts to about £10,750. (VIII. p. 92.)

Saxony.—The Royal Saxon Meteorological Institute was established at Chemnitz in 1864 by Prof. C. Bruhns and Prof. C. Krutzsch. Prof. Bruhns was the first Director, and Dr. Paul Schreiber, the present Director, was appointed in 1882. The number of stations attached to the Institute is between 160 and 170, of which 30 are of the second and third orders. Weather forecasts have not been issued since 1887, but they have been prepared, and the results of the checking are fairly good. The publications of the Institute contain the results of some very interesting investigations. The grant by the Government is about £2280 per annum. (IX. p. 92.)

Baden.—The Meteorological Service of Baden was founded in 1868 at Carlsruhe. It would seem to have been reorganised in 1882 and divided into two branches: (1) the Central Office for Meteorology and Hydrography, with Prof. Honsell as Director, and (2) Dr. Schultheiss was appointed Director of the Meteorological Branch. Attached to the system there are 17 stations of the second order, 32 rainfall stations, 70 thunderstorm stations, and 24 snowfall stations. Weather forecasts are only made to a limited extent, being only for those elements in which changes are expected, and their verification is not possible. Numerous interesting contributions have been published. The statement of expenses cannot be given exactly, as the expenses of the Central Office are borne by the Office of Waterworks and Highways; but for 1898 and 1899 a sum of £473 has been voted, which is exclusive of the personal expenses of the Director and his assistants (£600), which are paid from other funds. (X. p. 93.)

Greece.

The Meteorological Observatory at Athens was founded as a second order station in 1847, and up to 1890 there were practically only 3 stations attached to it. In 1890 the present Director, Dr. D. Eginitis, completed the Observatory, and it was provided with self-recording instruments in 1893. In the same year 19 additional second order stations were established, which send two telegraphic reports daily. Besides these, 55 foreign stations in Europe, Asia Minor, and Africa send

daily telegraphic reports for a Meteorological Bulletin; and preparations are being made for the publication of a bulletin dealing with curves and weather forecasts. The publications of the Observatory deal principally with the observations at Athens, and preparations are being made for the publication of the observations of the provincial stations. The budget for the meteorological department of the Observatory amounts to £380 for staff and other expenses, exclusive of the salary of the Director. (XI. p. 94.)

ITALY.

The Meteorological Service is extremely complicated. Observations were commenced at the Collegio Romano, the present seat of the Central Office in Rome, in 1787, and Padre Secchi erected his Meteorograph there in 1858. The Government took up Meteorology by a decree on December 13, 1863, and appointed a Committee for Weather Telegraphy. This gave rise to the Central Office with a superintending Council, and Prof. P. Tacchini as Director. The stations attached to the Central Office number 553. Weather forecasting is undertaken, but the percentage of success is not given. The publications are somewhat numerous and various. The cost of the service to the Government is not stated.

Moncalieri.—This is the home of the Italian Meteorological Society, which dates from 1859. The present Director is Count A. C. Vigodarzere, who succeeded the renowned Padre Denza. There are numerous stations attached to this Observatory. Weather forecasting is not undertaken. Many valuable communications have been published, and others are in preparation. The Society receives no ordinary grant from the Government. (XII. p. 95.)

The Vatican Observatory. Mention must be made of this observatory, at which very good work has been done.

NETHERLANDS.

The Royal Meteorological Institute of the Netherlands was founded at Utrecht by Royal decree of January 31, 1854, as the Government recognition of the work of Prof. Buys-Ballot and Dr. Krecke at Utrecht. It was divided into two portions: one for observations on shore, and the other for observations on board ship. Dr. Krecke was Director of the land section, and a marine officer of the sea section, whilst Buys-Ballot was Chief Director. Later on Dr. Snellen became Director of the land section, and Baron van Heerdt of the sea section. Long before his death on February 2, 1890, Buys-Ballot was looking out for larger quarters for the growing work of the Institute, and after his death the Government acquired the estate of De Bilt, in the neighbourhood of Utrecht, where the Institute is now housed. The present Director is Dr. M. Snellen. There are attached to the Institute about 306 stations, of which 6 are first order, 8 second order, 7 third order, 85 rain-gauge stations, and 200 thunderstorm stations. There are dependencies of the Institute at Amsterdam and Rotterdam. Forecasting work is undertaken, but the percentage of success has never been ascertained. Numerous works have been completed or are in progress, and a long list is given. The Institute is a Government establishment, and the annual grant is, in English money, about £3833. (XIII. p. 95.)

PORTUGAL.

The Observatory of the Infante Dom Luiz at Lisbon was founded in 1854 at the instance of Dr. Pegado, and various instruments were obtained. In 1863 the present Observatory was built by the King, Dom Luiz, at the instance of the Director, Fradesso da Silveira, who died in 1875, and was succeeded by Captain, now Admiral, J. C. de Brito Capello. At the end of 1864 there were 10 stations attached to the Observatory: 7 on the Continent, and 3 at Madeira and the Azores. Now there are 24 stations: 15 on the Continent (4 first order, 7 second order, and 4 third order), 3 in the Azores (2 first order and 1 second order), 1 at Funchal, and 5 in the Colonies. All the stations, except the colonial ones, send daily telegrams. By their aid, and the telegrams from Spain, France, and England, daily forecasts are issued. The percentage of successful forecasts has not been calculated. Various memoirs have been at times published, some of which rank very high, and several very interesting investigations are in progress. The present expenses for the observatories of the Continent and the Azores amount to about £1783. (XIV. p. 96.)

ROUMANIA.

In 1883 Dr. S. C. Hepites visited the Meteorological Offices in Europe, and consequent on his report the Roumanian Meteorological Institute was founded at the beginning of 1884. Towards its foundation Mr. V. Paapa of Bucharest gave £2000, and the Roumanian Government £4000, and £400 per annum. At the time of its foundation, only three stations were in existence, including Sulina, which had been established by the European Commission of the Danube in 1859. Dr. Hepites was appointed the first Director of the Institute, and still continues to hold that office. Attached to the Office are 357 stations, divided into 1 of the first order, 31 of the second order, 1 of the third order, and 324 rainfall stations. It is not stated whether forecasts are issued. The *Annales* contain valuable investigations relating to climate.

RUSSIA.

This very extensive system owes its origin to Baron A. von Humboldt and Prof. K. F. Gauss, through their advocacy of terrestrial magnetism. In 1837 Kuppfer, who published the observations on terrestrial magnetism, effected the establishment of an Observatory at St. Petersburg in 1840. On Kuppfer's death in 1865, Prof. Kämtz was appointed, to be succeeded, on his death in 1867, by Dr. H. Wild, who resigned in 1895 and was succeeded in 1896 by the present Director, Gen. M. Rykatcheff. In 1878 the Observatory was transferred to Pavlovsk. This system is the most extensive in the world, and the *Annales* for 1895 contained the detailed observations at 3 stations of the first order (those of Tiflis being published separately) and summaries of the observations of over 800 stations of the second order. The total number of second and third order stations is given as 2300. Weather forecasting is undertaken, but the percentage of success, which in the Chicago report of 1892 is stated at 81, is not now given. The percentage of success of storm warnings is, for the past ten years, given as 80 for the Baltic and 72·6

for the Black Sea. Besides the *Annales*, Kämtz commenced a *Repertorium für Meteorologie*, a publication which was afterwards resumed by Dr. Wild, and which contains very valuable papers on meteorological and kindred subjects. It is now closed. The expenses of the system, including the observatories, amount to about £44,922 per annum. (XV. p. 98.)

Finland.—This country possesses an independent system in connection with the Observatory at Helsingförs. I regret to say that I have no information about it.

SPAIN.

Practically no meteorological work was done in this country until 1850, when 23 meteorological stations, with the Madrid Observatory as a Central Station, were established by a Royal decree. The department was reorganised in July 1865 under Dr. A. Aguilar, and again in 1890 under Señor Augusto Arcimis, the present Director. The stations, so far as can be ascertained, number 45, of which 2 are first order and 43 second order. Forecasting is undertaken, but the percentage of success is not known. The expenses of the system cannot be stated, as they are exclusive of the salaries of the Central Station, and of telegraphy, which is free.

SWEDEN AND NORWAY.

Sweden.—Until 1859 meteorological observations were only taken at Stockholm, Upsala, and Lund. In that year Prof. Edlund, of the Royal Swedish Academy of Sciences, organised a series of stations. This commencement eventually gave way to the foundation by the State of a Meteorological Central Institute at Stockholm, which was placed under the care of the Royal Swedish Academy of Sciences, and was directed from the commencement by its present chief, Dr. Rubenson. Nautical meteorology is looked after by the Hydrographic Department, the Director of which is Commodore F. G. Malmberg. The number of stations attached to the Institute is 536, of which 1 is of the first order, 44 are of the second order, 341 of the third order, and 151 of the fourth order. Forecasting is undertaken, and the percentage of success in respect of rain and snow is about 80, the percentage for the other meteorological elements not having been ascertained. A list of numerous completed investigations is given. The Government grant for 1898 is about £1900. (XVI. p. 99.)

Norway.—The Meteorological Institute of Norway was established at Christiania in 1866, and its Chief has been from that date Prof. Dr. H. Mohn. It has now attached to it 430 stations, of which 3 are of the first order, 36 of the second order, 40 of the third order, and 351 rain-gauge stations. Storm warnings have been issued for the coast south of Bodö since 1869, and daily weather forecasts for Christiania have been issued from the same date. The percentage of success for precipitation is somewhat vague, being reckoned at from 85 to 90. Many interesting publications relating to the meteorology of Norway have been issued. The Government grant is about £2000. (XVII. p. 100.)

SWITZERLAND.

In 1824 the Swiss Society of Natural Philosophy had 12 meteorological stations superintended by a Committee. These were given up in

1837 owing to want of funds. In 1863 the Society established a new Meteorological Service with over 80 stations, and it was supported financially by the Federal Government and the Cantons. The organisation and superintendence was undertaken by a Committee, with its head office at the Observatory at Zurich. Gradually the activity of the Committee was reduced, and the work was almost exclusively carried on by the Office. On December 23, 1880, this organisation was practically superseded by the establishment of the Swiss Meteorological Office, with Dr. Billwiller, who had for some years superintended the old organisation, as its first and present Director. The new Office is placed under the Ministry of the Interior, with a superintending committee, called the Federal Meteorological Committee. The stations attached to the Office number 312, divided into 4 stations of the first order, 102 of the second order, 9 of the third order, and 197 rainfall stations. These latter stations will be very soon increased by about 100. Forecasting is undertaken, and the percentage of complete success is 70, and of partial success 25. Several investigations relating to the climate of the country are in progress. The annual vote from Government is now about £2200, and the miscellaneous receipts are about £160. (XVIII. p. 101.)

ASIA.

Hong Kong.

The Meteorological Organisation of Hong Kong was founded in 1883 by the present Director, Dr. Doberck, under instructions from the Government. The total number of stations is 65, of which 1 is of the first order, and the rest either of the second order or telegraphic reporting stations. Forecasting is undertaken, and the percentage of success reaches the very high figure of 96, and for gales and strong winds caused by typhoons 83. Numerous investigations, principally relating to typhoons, have been undertaken, and similar investigations are now in progress, but it appears likely that they will not lead to any further advance. The annual grant from Government is about £1500, and in addition the Eastern Extension and the Great Northern Telegraph Companies give free telegraphy. (XIX. p. 102.)

India.

Previously to 1864 meteorological observations had been practically only taken at the observatories of Madras, Bombay, and Calcutta, and for short periods at Simla, Dodabetta, and Trevandrum. There were also a few other scattered observatories of no great value, which were utilised by the von Schlagintweit's Scientific Mission to India. General Sir R. Strachey called the attention of the Asiatic Society to the need of systematic observations, and in 1864 the Society submitted a report to the Government. This report was similar to the scheme adopted in 1875. In 1864 the Government referred the matter to the Sanitary Committee, who recommended the system of Independent Local Reporters. This scheme proved defective. Sir R. Strachey called the attention of the Government to the defects, and it was decided to imperialise the work by combining the provincial systems into one system under an

Imperial Reporter. Mr. Blanford, the Meteorological Reporter of Bengal, was in 1874 requested to draw up the necessary scheme. This he did, and was himself appointed the first Reporter. He continued in office till 1887, and was succeeded by Mr. J. Eliot, the present Reporter. Attached to the department, or working in connection with it, are 227 observatories, which are scattered about the different provinces, divided into, we might say, four separate classes arranged according to their equipment. And in addition there are 2462 rain-gauge stations, which are maintained chiefly by the Provincial Revenue departments.

Weather forecasting in the European sense is not undertaken, but special forecasts are issued when required, and these are made as long as possible in advance. The percentage of success has not been calculated, it being considered as fallacious, owing to the special nature of the forecasts. The completed investigations number 53, and there are 4 investigations now in progress.

The Government grant is about £22,100, but, the telegraph lines being the property of the Government, the charge for telegraphy is purely nominal. (XX. p. 103.)

Ceylon.—I can get no information as to the meteorological organisation, beyond what is contained in the Scientific Report of the Surveyor-General for 1896. The head office of the system appears to be at Colombo, and there are stated to be 16 observatories and 73 rainfall stations attached to it. The observations of the 16 observatories, properly reduced, appear in the report, but not those of the rainfall stations. No particulars as to the money grant are given.

JAPAN.

In 1875 a Meteorological Service was established in the Land Survey section of the Geographical Bureau of the Home Department. After divers changes, the whole system was reorganised by an Imperial ordinance of August 3, 1887, and the rules were fixed by the Minister of Home Affairs in that year, and revised in 1892. Under this ordinance a Central Observatory was founded at Tokio; and numerous provincial stations, which were controlled by the different Prefectures, but were in communication with the Central Observatory, were established in suitable places. Mr. K. Kobayashi, the present Director of the Central Observatory, was appointed in 1891. The department has now attached to it about 25 first order stations and 49 second order stations, besides a large number of third order stations, some of which only report temperature and others only rainfall, and 84 lighthouse stations for wind observations only. For weather telegraphy there are 214 signal stations. Forecasting is undertaken, and the percentage of success is for weather 82, for wind 82, and for storm warnings only 67. Numerous investigations relating to the climate of Japan have been completed. The annual expenditure provided by the Government and the Prefectures is about £7632, together with free telegraphy and postage.

JAVA.

The foundation of the Meteorological Observatory at Batavia was due to a suggestion made by Baron Alexander von Humboldt to the Governor-

General of the Netherlands India, the Chevalier F. Pahud, in 1856; and ten years later hourly observations were made there, and the Observatory was officially established in 1875. The present Director is Dr. van der Stok, and the Sub-Director Dr. S. Figee. There seem to be no second or third order stations attached to the Observatory, but there are 213 rain stations, 83 tidal stations, and 85 wind stations. Weather forecasting does not seem to be undertaken. Several interesting investigations have been completed, and three are now in progress—investigations relating to Cloud, Daylight, and Tidal Constants. The Observatory is under the control of the Commander of the Fleet, and the expenses are provided by the Government and amount to £3000 per annum. (XXI. p. 106.)

AUSTRALASIA.

New South Wales.

Meteorological observations would appear to have been commenced at Sydney in 1821, when Sir T. Brisbane was appointed Governor, but most of the records, with the exception of a few intermittent rain records, are now lost. From 1841 to 1855 observations were carried on at South Head, 5 miles east of Sydney, when they ceased. Prof. S. Jevons was, however, then taking observations in Sydney, and he continued the work until the Sydney Observatory was founded in 1859. The present chief, Mr. H. C. Russell, was appointed in 1870, and he at once began to extend the meteorological organisation, which had somewhat languished. The International Exhibition at Sydney in 1879 gave an opportunity for great improvement, owing to the calling together of a Conference of the heads of the different meteorological organisations in Australasia. The stations attached to the organisation now number 192, comprising 31 of the first order, 65 of the second order, and the remaining 96 simply report wind and weather. Forecasting is undertaken, and is much aided by the reports from the other Australasian colonies. The percentage of success reaches the high total of 90. The published works are very few. The grant from Government for Meteorology is £2240, and this is exclusive of half of the salary of Mr. Russell, who divides his time between astronomy and meteorology. (XXII. p. 108.)

New Zealand.

The particulars relating to the Meteorological Organisation in this country that I have been able to procure are somewhat scanty. There appear to be no meteorological publications so called, and the only statistics are those published in the Registrar-General's reports commencing in 1853. From that date till 1859 they are of small value, but after 1859 they are good. The present head of the system is Sir James Hector, who was appointed in 1867. There are 9 stations, which appear to be second order stations, whose records are published in the Registrar-General's reports, and about 80 rain-gauge stations. Forecasting is undertaken, but the percentage of success is unknown. The cost to the Government of the system is also not stated.

QUEENSLAND.

In January 1887 the Government established a Meteorological Bureau as a branch of the Post and Telegraph Department, and entrusted the work of organisation and management to Mr. Clement L. Wragge. He threw himself energetically into the work, with the result that there are now attached to the system 23 first order stations, 47 second order stations, 70 third order stations, 23 third order A stations, and 464 third order B stations. A total number of 627 stations. Forecasting has been undertaken, and forecasts have been issued for the whole of Australasia since 1887. The percentage of success averages between 90 and 93. Numerous investigations relating to the climate of Queensland, and to ocean currents, and the reduction of the observations at the Australasian high-level stations, are in progress. The annual Government grant varies from £1600 to £1650. (XXIII. p. 110.)

SOUTH AUSTRALIA.

The honour of first making systematic observations in South Australia may be said to rest with Sir G. Kingston, who took rainfall records at Adelaide from 1839 till 1878. Meteorological observations were made at the Survey Office for several years prior to 1856, when the Observatory records were commenced under the direction of the Postmaster-General, Sir Charles Todd. From 1860 the observations have been made at West Terrace Observatory. Attached to the system there were, in 1898, 473 stations, of which 1 is of the first order, 22 are of the second order, and 456 are rain-gauge stations. Forecasting was commenced in October 1888, and the percentage of verified success for the 10 years 1889-98 is 75, which seems somewhat small, and of partial success 19. There seem to have been no special investigations, either completed or in progress. No details of the amount granted by the Government, or the expenditure thereof, can be furnished, as the same are merged in the grant for the Observatory. (XXIV. p. 111.)

TASMANIA.

Meteorological observations were begun in 1840, when Capt. Sir John Franklin was Governor. He established an Observatory near Government House, and put Lieut. Kay in charge. Mr. Francis Abbott carried on observations from 1841 to 1880 at his observatory in Murray Street, Hobart, which were published by the Royal Society of Tasmania in their annual volumes. Observations were also started by the Marine Board at the lighthouses, and by various private persons. When Mr. Abbott relinquished his work in 1880, the Royal Society in 1882 induced Capt. Shortt to undertake it, and in 1883 appointed a deputation to wait on the Premier with the object of asking him to establish a Government Observatory. The present Observatory in the Barracks was then started, with Capt. Shortt in charge of it until his death in 1892, when Mr. H. C. Kingsmill was appointed Meteorologist. Attached to the Observatory are 75 stations, of which 2 are of the first order, 6 of the second order, 2 climatological stations, and 66 rainfall stations. No weather forecasting is undertaken. The investigations now completed relate to the climate of Hobart, and two valuable investigations

are in progress. The Government grant for the Meteorological Department is £325. (XXV. p. 112.)

VICTORIA.

Prior to 1855 there are practically no meteorological records. In that year, systematic observations at Melbourne and a few other places were commenced under the control of the Crown Lands Department. On March 1, 1859, Prof. Neumayer took up the work at his own Observatory, and carried it on till 1863, when he returned to Europe. In that year Prof. Neumayer's Observatory was amalgamated with the Astronomical Observatory under Mr. Ellery, who expanded it continually up to his retirement in June 1895, when Mr. P. Baracchi succeeded him. The Meteorological Service under the control of the Observatory is divided into 3 divisions: (1) the Inter-Colonial Daily Weather Service, (2) the Local Daily Weather Service, and (3) the Statistical Monthly Service. The number of stations attached to the service is 573, of which 20 are barometric stations, 40 temperature stations, and 513 simple rainfall stations. Forecasting is undertaken, and the present percentage of success is 85; and this seems a relatively high percentage, having regard to the fact that it is often necessary to forecast for four separate areas of the country, each of which possesses its own distinct weather type. No special investigations have been completed or are in progress. With respect to the expenditure, as the Meteorological and Astronomical sides of the Observatory have been amalgamated, this can only be estimated at about £2300. (XXVI. p. 112.)

WESTERN AUSTRALIA.

In January 1876 a branch of the Surveyor-General's Department for Meteorology was established under the superintendence of Sir Malcolm Fraser. Gradually the work progressed, owing to the energy of Mr. M. A. C. Fraser, who was the Meteorological Reporter, and had practically charge of the work from the commencement. In February 1896 the Government decided to build an Astronomical Observatory at Perth, and appointed Mr. W. E. Cooke, Astronomer, giving him also charge of the Meteorological Department. This was reorganised and the stations properly inspected. The Observatory is not yet finished, but the Meteorological Department of it is practically equipped as a first order station. Attached to the Observatory are 31 stations of the second order, and 218 rain-gauge stations. Weather forecasting commenced in January 1898, and for the first 6 months the percentage of complete success was 93, and of partial success 6. No investigations have yet been undertaken. The expenditure for 1897 was £3068, which was mostly spent for meteorological purposes, owing in a great measure to the astronomical instruments not being in working order. (XXVII. p. 114.)

AFRICA.

CAPE COLONY.

Meteorological observations have been made in various parts of the country from 1820, but they do not seem to have been of any great value,

though some of them from 1831 to 1837 were published in the Reports of the South African Institution, which was founded in 1831. By a Government notice dated October 26, 1860, a Meteorological Commission was appointed, which reported on July 7, 1862. The Commission was reappointed in 1865. In 1875 the system was reorganised, and the Chairman then appointed was the Hon. C. A. Smith, who still continues, whilst the present Secretary is Mr. Charles Stewart, who was appointed in 1897. The stations attached to the system number 451, of which 54 are of the second order, 19 of the third order, and 378 rainfall stations. No forecasting has been as yet undertaken, and the only investigation completed relates to rainfall. The Government vote is £600 per annum, to include every expense except the cost of rain-gauges, which falls on the Public Works Department. (XXVIII. p. 115.)

Mauritius.

The first mention of Meteorology is in 1695, but no observations were made until Mr. Leslet Geoffrey commenced his observations in 1786, and continued them till 1792. The first attempt at establishing a Government Observatory was made by Col. Lloyd, the Surveyor-General, in 1830. He commenced observations on January 1, 1832, and they ceased in 1849. On August 1, 1851, the Mauritius Meteorological Society was founded, and took up the matter, and the Government gave it an annual grant of £200, out of which to pay the Government Meteorologist £100, the rent of the Observatory building £60, and the salary of an assistant £36. Mr. Bousquet was appointed Meteorological Observer in 1852, and was succeeded by Lieut. Fyers in 1855, and by Capt. Stokes in August 1858. The meteorological instruments, which had been lying idle, were brought into use in 1859. In March 1862 Dr. Meldrum was appointed Government Observer. In the meantime the Society had requested the Government to sell the old Observatory, which was badly placed, and with the proceeds to build a new one. This was eventually done, and a new Observatory—the foundation-stone of which was laid by H.R.H. Duke of Edinburgh—was built at Pamplemousses, 7 miles north-north-east of Port Louis. The Observatory was practically not finished till 1875, when the meteorological instruments were installed in it, the observations having in the meantime been made elsewhere. In the same year Dr. Meldrum's designation was changed to that of "Director of the Royal Alfred Observatory," and he filled the post till 1896, when he was succeeded by Mr. T. F. Claxton, the present Director.

Attached to the Observatory are 70 rainfall stations, from 6 of which temperature records are also received. Storm warnings are issued, but owing to the want of telegraphs no forecast is possible. Numerous investigations, relating mostly to storms, have been completed, and an investigation into the cause of the diurnal variation of the rainfall of Mauritius is engaging attention. The maintenance of the Observatory costs the Government about £1300 per annum. (XXIX. p. 117.)

Natal.

The Meteorological Organisation is in a very unsatisfactory state. From about 1872 till the founding of the Astronomical Observatory at

Durban an annual grant was made to the Botanic Societies of Durban and Maritzburg, conditionally on their making meteorological observations, which they did somewhat irregularly, but these records are lost.[1] From 1883 till 1891 the only observations were those of the Astronomical Observatory. In 1891 a small grant was given to furnish 5 stations, in 1893 8 more stations were furnished, and in 1895 another 8, but great difficulty is found in obtaining regular observations. No forecasting or other meteorological work is undertaken. The present head of the system is Mr. E. Nevill, the Government Astronomer, and no special vote is made by the Government for meteorological work, the expense coming out of the ordinary vote for the Astronomical Observatory. The actual cost of the meteorological work is about £200 per annum. (XXX. p. 119.)

AMERICA.

CANADA.

At the Toronto Magnetical Observatory meteorological observations have been carried on without a break since 1841. Prior to 1869 there was no unity of action amongst the different meteorological observers, but in that year Prof. G. T. Kingston, the Director of the Toronto Observatory, communicated with the observers, asking their co-operation. From October 1869 to the spring of 1871 this voluntary work was gratuitously performed by Prof. Kingston. In the spring of 1871 the Government made its first grant, with a special view of preparing the way, for a system of storm-signals. The grant was gradually increased as a result of the progressive efficiency of the service. In September 1876 the Canadian system, which up to that date had relied on the courtesy of the U.S. for its storm warnings, first issued warnings to the Canadian ports. Attached to the system there are now, in accordance with the International classification, the following stations: 4 of the first order, 65 of the second order, 206 of the third order, and 89 rainfall stations. Weather forecasting is undertaken, and the percentage of success in 1897 was for storm warnings 84·9, and for the daily 36-hour forecasts 81·4. The grant for 1898 from Government is £12,936. The Chiefs of the system have been Prof. Kingston till 1880, Mr. Charles Carpmael till 1894, and then the present Chief, Mr. R. F. Stupart. (XXXI. p. 120.)

MEXICO.

Meteorological observations seem to have been carried on more or less continuously from 1768 till March 6, 1877, when the Central Meteorological Observatory was founded by the President, Porferio Diaz, at the suggestion of General Vicente Reva Palacio, the Secretary of Public Works. All the other stations were gradually absorbed into the

[1] The late Dr. R. J. Mann, the Superintendent-General of Education in the Colony, 1857-66, published several papers: one an "Abstract of Five Years' Observations made at Maritzburg, Natal, 1858-62," and another, "Abstracts for 1864 and Results for Six Previous Years." Two years of the Observations appear in the 5th No. of *Meteorological Papers of the Board of Trade*, published by Admiral Fitz-Roy, and a paper on the results, 1860-65, is printed in the *Quarterly Journal of the Royal Meteorological Society*, vol. iv. p. 173.—EDITORS.

system. The first and present Director is Mariano Bárcena [recently deceased, April 1899], the Vice-Director being Miguel Perez, and the second observer, the present Sub-Director, José Zendejas. Attached to the organisation are the following stations: 1 of the first order, 28 of the second order, and numerous stations of what may be called the third order. Weather forecasts are not issued. There appear to be no special investigations either completed or in progress. The total expenses of the system may be stated at £8600. (XXXII. p. 122.)

The United States.

The great organisation of the Weather Bureau arose from small beginnings. In 1807 a system of daily weather observations was started, and in 1819 observations for climatological purposes were instituted as a duty of the Medical Staff of the Army. In 1825 the Regents of the University of the State of New York established a system of stations, and in 1837 the State of Pennsylvania granted funds for the expenses of stations in that State. In 1841 the Commissioner of Patents established a system of climatological reports in connection with crop statistics. The Patent Office in 1849 became a department of the Interior. In 1847 the Smithsonian Institution started its system of stations, which finally extended over the whole of the habitable part of North America, which continued till 1873, when the records were deposited with the Signal Office. In 1863 the Chief of Engineers of the U.S. Army organised a system of stations covering the region of the Great Lakes, and as early as 1864 it was found that the system could be made available for storm prediction; and in 1869 the Cincinnati Observatory commenced a system of weather reports and predictions. The above now led up to the passing of the resolution of Congress of February 9, 1870, authorising the Secretary for War to take observations. This duty was committed to the Chief Signal Officer of the U.S. Army. The work was most ably carried on by the different Chief Signal Officers till October 1, 1890, when the meteorological duties of the Chief Signal Officer were transferred to the Department of Agriculture by Act of Congress, and the organisation became the Weather Bureau. In 1898 Congress added the region traversed by the West Indian hurricanes before they enter the States. The first Chief of the Weather Bureau was Prof. Mark W. Harrington, who was succeeded on July 1, 1895, by the present Chief, Prof. Willis L. Moore. The stations attached to or in communication with the Bureau are extremely numerous: (1) 149 first order stations; (2) 417 for temperature and rainfall, or the height of rivers and rainfall; (3) 3000 voluntary observers, like the Royal Meteorological Society's climatological stations; (4) the 12 West Indian stations; (5) the stations of the Surgeon General of the U.S. Army; (6) the observers on the ocean reporting to the Hydrographer of the U.S. Navy, who now number several thousands. Weather forecasting is a great feature of the organisation, and the percentage of success is as follows:—for 36 hours in advance, weather 85, temperature 83; for 48 hours in advance, weather 81, temperature 75; wind signals 24 hours in advance, cautionary 70, storm wind 80, cold wave 75; and for river and flood predictions 100. The list of completed works is exceedingly long and valuable. The works in

progress are Prof. Bigelow's on recent cloud work, and Prof. Marvin's on kite work. The vote of Congress is £195,000—an amount which seems large, though it is, with the exception of a very small sum, specifically appropriated. (XXXIII. p. 123.)

ARGENTINE REPUBLIC.

The Argentine Meteorological Office was founded at the instigation of Dr. B. A. Gould, by an Act of Congress passed in October 1872. The organisation was gradually extended by Dr. Gould until his retirement in 1884. At the beginning of 1885 Mr. W. G. Davis was appointed Director of the Meteorological Office, which in May of that year was moved from the Astronomical Observatory to its present quarters at Cordoba. Attached to the Office there is 1 first order station, 10 second order stations (the most northerly of which is at Asuncion in Paraguay), 24 third order stations, and 136 fourth order stations. Forecasting is not undertaken, owing to the absence of telegraphic facilities. The published investigations relate principally to the observations of the contributing stations, but there are two investigations in progress which seem of sufficient importance for mention, viz. on evaporation and on earth temperatures. The annual grant from Congress is 35,940 paper dollars, which at the present gold premium is equal to about £3365. (XXXIV. p. 129.)

BRAZIL.

The system in this country seems at present to be rather one in name. The Central Meteorological Office was established at the Ministry of Marine in 1885 under the Director, Capt. A. P. Pinheiro, who died in June 1896. He was succeeded by Lieut.-Commander A. Silvado, assisted by Lieut.-Commander S. de Moura. There is an observatory of the first order at Rio de Janeiro under Dr. Cruls, the astronomer, but there does not appear to be any system of stations attached to it, though there seem to be independent organisations in the provinces of São Paulo, Porto Alegre, and Rio Grande do Sul. There would appear to be no forecasting, or investigations completed or in progress; and the expense to the Government is not stated, but is probably small.

JAMAICA.

This service was established in 1880. The head office appears to be at Kingston, but Mr. Maxwell Hall, the superintendent, does not live there, but at Montego Bay, 78 miles distant, his place at Kingston being taken by Mr. Robert Johnstone, with Mr. J. F. Brennan as assistant. There appear to be 1 first order station, 3 second order stations, 5 third order stations, and about 200 rainfall stations. Forecasting for cyclones has been undertaken, and has been very successful, no mistake having been made; but for rainfall it has been, for various reasons, the reverse, and has been given up. Numerous investigations have been completed, and there is in progress one connected with cyclones. The grant from Government is £150, out of which Mr. Hall has to pay his assistants and find his own instruments. In addition, the Government give free stationery, printing, and telegraphy.[1] (XXXV. p. 131.)

[1] We are sorry to learn that the Government grant has been withdrawn (December 13, 1898) owing to the financial depression of the island.—EDITORS.

Such is the abstract of the replies which I have received, and of the information which I have been able to gather together in the ways indicated at the commencement of this Address. I have thought it advisable to endeavour to find out, if possible, what proportion the Meteorological grant of the different organisations bore to the population of the different countries which have an official organisation for Meteorology. I have therefore prepared the accompanying table, giving the areas in square miles and also the populations, together with the grants. The areas and populations I have ventured to take from *Whitaker's Almanack* for the present year. A single glance at this table will show what a very

AREA, POPULATION, AND GRANT FOR METEOROLOGY.

Country.	Area.	Population.	Grant.
EUROPE.	Square miles.		
Austro-Hungary	261,649	44,901,036	£5000*
Belgium	11,373	6,586,593	2000
British Isles	120,190	37,880,792	15,300*
Denmark	14,789	2,185,335	4,300
France	204,146	38,517,975	7,300*
German Empire	211,168	52,246,589	...
Greece	24,977	2,433,806	380*
Italy	110,623	31,479,217	...
Netherlands	12,582	4,859,451	3,833
Portugal	35,843	4,708,178	1,783
Roumania	46,314	5,500,500	400
Russia	8,450,081	129,211,113	44,922
Spain	196,173	17,550,216	...
Sweden and Norway	299,377	7,044,568	3,900
Switzerland	15,469	2,933,334	2,200
ASIA.			
Hong-Kong	30½	248,710	1,500*
India and Ceylon	1,585,525	290,521,773	22,100*
Japan	162,655	42,270,628	7,623*
Java	718,000	34,273,561	3,000
AUSTRALASIA.			
New South Wales	310,700	1,335,800	2,240
New Zealand	104,471	743,214	...
Queensland	668,497	484,700	1,625
South Australia	903,690	358,224	...
Tasmania	26,215	166,113	325
Victoria	87,884	1,169,484	2,300
Western Australia	975,920	171,021	3,068
AFRICA.			
Cape Colony	277,151	1,875,960	600*
Mauritius	705	377,856	1,300
Natal	20,851	630,817	200
AMERICA.			
Canada	3,315,649	5,250,000	12,936
Mexico	751,177	10,447,974	8,600
United States	3,025,600	62,630,250	195,000
Argentine Republic	1,212,000	4,093,000	3,365
Brazil	3,218,166	17,000,000	...
Jamaica	4,193	639,491	200*

* Exclusive of certain allowances (either free postage, telegraphy, printing, or stationery).

small portion of the revenue of the different countries goes towards the promotion of this science, in which we are here so greatly interested. To take the United States, whose grant is larger than that of all the other countries put together, it is, when we come to calculate it out, a little over one shilling per square mile, and about three farthings per head. In the British Isles it is two shillings and sixpence per square mile, but only about one-third of a farthing per head. In Russia it is a little over one penny per square mile, but only a little over one-third of a farthing per head; whilst in India and Ceylon it is about fourpence half-penny per square mile, and less than one-tenth of a farthing per head; and in Canada, the only remaining country which gives a grant amounting to five figures, it is just one penny per square mile, and rather over one half-penny per head. I think that we may fairly assume that in no case will it be found that the Meteorological grant exceeds the amount of three farthings per head of the population of the country making the grant. I will leave it to you to consider whether, having regard to the vast interests which will be benefited by the further progress of this science, the small sums granted are at all adequate.

In conclusion, I desire to thank you for the kindness and attention with which you have listened to this somewhat long Address, but I trust that the photographs of the eminent men who are at the head of these different organisations, and of the different places which form their head-quarters, which have been shown upon the screen, will make amends for any shortcomings on my part, and will make you feel charitably disposed towards me.

APPENDIX.

I.—Austro-Hungarian Empire.

Central Institute for Meteorology and Terrestrial Magnetism, Vienna.—Prof. J. M. Pernter, Director.

1. The Central Anstalt for Meteorology and Terrestrial Magnetism was established in July 1851 by Imperial decree of His Majesty the present reigning Emperor. Its duty was to organise the meteorological observations in the whole monarchy, to supervise and extend them, and to make such arrangements at the Central Office as should not only promote the usual observations, but also fundamental investigations. It was also to further the progress of meteorology and terrestrial magnetism to the fullest extent by scientific discussions.

The following have been the successive Directors:—(1) Prof. Karl Kreil, 1851-63; (2) Prof. Karl Jelinek, 1863-76; (3) Prof. Julius Hann, 1877-97; (4) Prof. J. M. Pernter, from 1897. The organisation of the Central Office has developed from small beginnings. Originally it only consisted of the Director, one adjunct, and one assistant, who shared in the labours at the Observatory, and in the discussion of the data furnished by the stations. In 1872 a special building was erected for the Central Office, which was fully equipped as the Central Observatory, and sufficient space was provided for the management of the stations. At that time three adjuncts, two assistants, with computers, mechanician, and two servants, were at the disposal of the Director. The adjuncts undertook the observations and the discussion of the data from the stations, in which the assistants also took part. This organisation remains

the same at the present time. The duties performed by the Central Office at present are as follows:—

1. The management of the Central Observatory, reduction, discussion, and publication of the records of the self-registering instruments.

2. Discussion and publication of the observations received from the stations.

(3). Telegraphic weather service and daily weather forecasts.

(4). Magnetic observations, reduction and publication of the records of the self-registering magnetic instruments.

In addition, the scientific discussion of the existing materials is actively carried on.

2. The stations consist of 25 of the first order, 175 of the second order, 230 of the third order, and 76 of the fourth order.

3. About 85 per cent of success.

4. The investigations by the Director and scientific staff are so numerous that I must refrain from giving a list of them. Most of them are so well known to the meteorological world that their enumeration is superfluous.

5. No special investigation is now in progress by the Central Office.

6. The expenses are at present:—For staff, 18,000 florins (at 1s. 8d., say £1500); for scientific purposes, 13,000 florins (say £1084); other expenses, 3500 florins (say £292).

II.—Pola.

Hydrographic Office, Pola.—Rear-Admiral A. von Kalmár, Director.

In reply to your letter of the 10th instant, I beg to inform you that the questions put can only be answered by the Director of the Central Office for Meteorology, etc., at Vienna. There is a second central office in this kingdom, viz. the Royal Hungarian Institute for Meteorology and Terrestrial Magnetism, to which the stations in the territories of the Hungarian Crown belong.

With regard to Pola, there is a meteorological and magnetic observatory of the first order attached to the Hydrographic Office of the Navy. This being a marine observatory, it is not subordinate to the Central Office in Vienna, but forms, with other physical duties to perform, the Fifth Division (Geophysics) of the Hydrographic Office.

The organisation of this division, the description of the meteorological and magnetical instruments, as well as of the methods of observation, and historical sketch relating to the development of the meteorological and magnetical service at Pola, will be found in the Introduction to the *Year Book . . . New Series, Observations for the Year* 1896, and in the following Year Books all changes in the instruments and methods of observation are fully discussed. These publications are sent yearly to the Royal Meteorological Society, and must therefore be accessible to you.

In addition to Pola, the Admiralty possesses two stations of the second order, at Sebenico and Teodo (Bocche di Cattaro).

The observations made at Sebenico have been published in the periodicals of the Hydrographic Office since May 1890; the station at Teodo has only existed since 1893, and the observations will be published next year.

Finally, three rainfall stations have been established since 1891 in the vicinity of Pola [names specified]; these observations will be found in the official publications.

The Hydrographic Office was reorganised in 1869; the Directors were:—September 1869 to December 1870, Dr. F. Paugger; January 1871 to August 1894, Dr. R. Muller; August 1894 to present time, Admiral A. von Kalmár. The meteorological observations which had been made since 1895 in the [illegible] "Sternwarte" were undertaken by the new department "Geophysik,"

which was then established. From January 1, 1896, Lieut. W. Kesslitz was appointed Director. The vote for this division is at present 1500 florins (say £125), exclusive of the cost of publications and other printing.

III.—Belgium.

Royal Observatory, Uccle.—Mons. A. Lancaster, Director.

1. The Royal Observatory of Brussels was founded in 1826 by A. Quetelet, but did not commence regular work until 1833. From the first, Meteorology occupied a large place. Quetelet had a predilection for this science, and published a long list of works, some of which—such as "The Climate of Belgium" and "Physics of the Globe"—are still considered as models of scientific discussion.

A certain number of stations were established about the year 1845 in Agricultural Schools and in the Civil and Military Hospitals. But they disappeared one after the other, from various causes, and at the time of the death of Quetelet, in 1874, only 4 stations remained. The appointment of Houzeau, two years later, marks the opening of a new era for Meteorology in Belgium. In the year 1880 the climatological system numbered 72 stations, and since that time it has never ceased to increase. In 1881 a system of rainfall stations was started, and at the present time numbers about 250, and the observations have been utilised in the "Rainfall Chart of Belgium," published in 1895.

M. Folie succeeded M. Houzeau in 1885. He chiefly directed his attention to the establishment of a service of agricultural meteorology. A memoir "On the Applications of Meteorology to Agriculture" is reprinted in the *Annuaire* of the Observatory for 1896.

2. Among the regular publications may be mentioned:—

The "Daily Weather Report." In addition to telegraphic reports and chart, it contains forecasts for the ensuing 24 hours.

Another publication (containing 20 quarto pages per month) is devoted exclusively to observations made at Uccle. There is also a "Monthly Bulletin" (containing 4 quarto pages) giving a summary of the observations made at over 240 stations, and the results are also used in *Ciel et Terre* and in the *Annuaire*.

3. Telegrams are sent each day to fishery stations, giving a general summary of the weather; and storm-warning telegrams are sent to the ports, based on notices received from the Meteorological Office in London. Occasionally warnings are also sent to collieries.

5. Since the year 1896 the Observatory has been officially charged with the duty of preparing statistics of damage by lightning, and is also in co-operation with the Director of Waters and Forests, and the Society of Public Medicine.

6. In 1897 the vote for Meteorology was 50,000 francs. The staff consisted of seven persons, some of whom were connected with other services.

IV.—The British Isles.

Meteorological Office, London.—Mr. R. H. Scott, D.Sc., F.R.S., Secretary.

1. The primary object for which the Meteorological Office and all other similar offices were established was the acceleration of ocean routes for vessels by an accurate investigation of the prevalent winds and currents in various parts of the sea.

The first impulse was given by F.M. Sir J. Fox Burgoyne, R.E., who in 1852 started the idea of land observations to be carried out by the Royal

Engineers. The United States authorities were then consulted by our Government as to their co-operation, and they suggested its extension to sea observations. The Royal Society also warmly supported the scheme for Marine Meteorology.

In 1853 the Brussels Conference met in August, and was attended by most of the maritime nations, and a uniform plan was adopted. At the end of 1854 Mr. Cardwell, the then President of the Board of Trade, resolved to establish a Meteorological Department in connection with the Marine Department of that Office, and appointed Admiral (then Captain) Fitz-Roy as its chief. Admiral Fitz-Roy worked very hard at Marine Meteorology until 1860, when he turned his attention to Weather Telegraphy, and to him is mainly due the credit of establishing the now general system of storm-warning signals. Admiral Fitz-Roy died in 1865, and in 1867 the Government placed the management of the Office under a Committee of the Royal Society, with Sir Edward Sabine as Chairman, and Mr. Robert H. Scott was appointed Director. This Committee continued Admiral Fitz-Roy's work in Marine Meteorology and Weather Telegraphy, and added a new branch, viz. Land Meteorology. In 1877 the Office was reconstituted and placed under the management of the Meteorological Council, who are nominated by the Royal Society and appointed by the Government. The first Chairman was Prof. H. J. S. Smith, F.R.S., who died in 1883, and was succeeded by Lieut.-Gen. Sir R. Strachey, G.C.S.I., F.R.S.

2. There are seven categories of stations in connection with the Office, and they were at the end of 1896 as follows:—

(1) Observatories	7
(2) Anemographic Stations	15
(3) Barographic (Aneroid) Stations	15
(4) Sunshine Stations	62
(5) Telegraphic Stations	30
(6) Second Order Stations	79
(7) Third Order Stations	61
Total	269

All these stations are regularly inspected.

3. Forecasting is undertaken, and the detailed comparison of the forecasts with actuality is as follows:—

The 8.30 p.m. Forecasts 1896-97	81 per cent
,, ,, ,, for ten years 1887-96	81·6 per cent
Hay Harvest Forecasts 1896	88 per cent
Storm Warnings, 1896	91·5 per cent
,, ,, for ten years 1887-96	87·3 per cent

4. The publications of the Meteorological Office are divided into two classes. Up to 1896 the "official" publications numbered 132 and the "non-official" ones 17, and a list is published in the Annual Report.

5. Several investigations are in progress.

6. The Government grant to the Meteorological Office an annual subsidy of £15,300, and in 1896-97 the miscellaneous receipts amounted to £931 : 8 : 6, making a total of £16,231 : 8 : 6. The expenditure amounted to £15,974 : 6 : 2, which included a sum of £1725 : 8 : 7 paid to the Post Office on account of inland and foreign telegrams, allowances to telegraph clerks, rental of private wires, etc. In addition to the grant of £15,300, the Government also give free printing.

V.—Denmark.

Danish Meteorological Institute, Copenhagen.—Dr. A. Paulsen, Director.

1. The Danish Meteorological Institute at Copenhagen was established in April 1872. The Directors have been—1872-84, Captain N. Hoffmeyer; and 1884 to present time, Dr. Adam Paulsen.

2. The Climatological Service was commenced in 1872; the Weather Service (with 18 telegraphic stations, now 42) in 1873; and the Nautical Service in 1879. Systematic Tide Observations, by means of mareographs, were commenced in 1886; and the Magnetical Service in 1888.

The stations now comprise the following:—(*a*) in Denmark—first order, 1; second order, 14; climatological, 129; rain-gauge, 107: (*b*) in Faroe Islands—second order, 1; climatological, 3: (*c*) in Iceland—second order, 4; climatological, 13: and (*d*) in Greenland—second order, 5; climatological, 5.

3. Weather forecasts have been issued once daily, based on the morning telegrams, since 1880. The percentage of success has been 82. These forecasts are distributed to all Danish telegraphic stations and published there. Forecasts for agricultural purposes, based on the afternoon telegrams, have been issued daily during the summer months since 1883. These have been distributed to all Danish telegraphic stations and railway stations, and published by means of posters.

6. The amount of grant from our Government is £4300 per annum, of which £500 is for Distribution of Telegrams, £500 for the Magnetical Service, and £450 for the Mareographical Service.

VI.—France.

Bureau Central Météorologique de France, Paris.—Prof. E. Mascart, Director.

1. The Meteorological Service of France was established in 1855 by Le Verrier, and formed a special branch of the Observatory of Paris until his death. At that time it was constituted an independent service, under the name of Central Meteorological Office of France, by a decree dated 14th May 1878.

Details of the organisation of the Office are given in the Introduction to vol. i. of our *Annales* for 1878.

2. The stations under our control, and from which we receive observations regularly, are: 12 stations of the first order, 5 mountain stations, 183 stations of the second order (taking from three to six observations daily), and 2036 stations of the third order (including rainfall stations). We have also established a certain number of stations in our colonies; the number increases each year. You will find the summary of all these observations in vol. ii. of our *Annales* for 1896.

3. Forecasts are issued. In the *Annales* for 1895, part i., 92 per cent success is claimed.

6. The expense of the Service is about £7300 (exclusive of allowances to the mountain stations of Pic-du-Midi and Puy-de-Dôme).

VII.—German Empire.

Deutsche Seewarte, Hamburg.—Dr. G. Neumayer, Director.

Herewith I send you the following publications, from which the information desired can be obtained:—

1. *First Annual Report on the Organisation and Work of the Deutsche Seewarte.*
2. *Die Deutsche Seewarte*, i. Description of the Central Office at Hamburg, by Dr. Neumayer.
3. *Report of the Proceedings of the International Meteorological Committee at Copenhagen, August* 1-4, 1882 (pp. 38-44 contain particulars about the Seewarte).
4. *Twentieth Annual Report on the Work of the Deutsche Seewarte*, 1897.

If I can be of any assistance in completing any of the particulars, I am quite at your disposal.

VIII.—Prussia.

Royal Meteorological Institute of Prussia, Berlin.—Dr. W. von Bezold, Director.

1. The Royal Prussian Meteorological Institute was established, at the instance of A. von Humboldt, by a Cabinet decree of October 17, 1847, and was incorporated with the Royal Statistical Bureau.

Until April 1, 1886, it formed a special scientific branch of that Bureau, with which it was administratively connected.

After that date it became an independent scientific institution, placed directly under the Prussian Ministry of Worship.

The Directors of the Institute were:—1847-48, W. Mahlmann; 1849-79, H. W. Dove; 1879-83, T. A. Arndt, *ad interim;* 1883-85, G. Hellmann, *ad interim;* 1886 to present time, W. von Bezold.

2. The Institute has to perform essentially purely scientific duties. It possesses in Prussia a large network of stations, and a meteorological and magnetical observatory of the first order at Potsdam.

The non-Prussian States of North Germany, such as Mecklenburg, Oldenburg, etc., have, with their system of stations, joined the Prussian Institute, which discusses and publishes their observations in the same way as its own.

There are at present 122 stations of the first and second order, 60 stations of the third order, 2000 rain stations, and 1400 thunderstorm stations.

3. Weather forecasts are not issued.

4. Numerous meteorological, climatological, and magnetical investigations by the Director and officials of the Institute have been published, about which the yearly Reports give particulars.

5. The following may be mentioned among the larger discussions now in progress:—

(1) Issue of a large work on the distribution of rainfall of the North German river basins.

(2) Publication of special rain-charts for the different provinces.

(3) An extensive magnetic survey.

(4) Issue of a work on the physical conditions of the upper atmosphere. This work is not undertaken by the Institute, but by officials essentially co-operating with it.

6. The annual budget of the Institute amounts in the financial year 1897-98 to 215,000 marks (say £10,750).

IX.—Saxony.

Royal Saxon Meteorological Institute, Chemnitz.—Dr. P. Schreiber, Director.

1. The Royal Saxon Meteorological Institute was established in 1864, by Prof. C. Bruhns, at Leipzig, and C. Krutzsch of Tharandt (Forest Academy).

The first Director was Prof. C. Bruhns, until 1882, when Dr. Paul Schreiber undertook the management.

2. There are about 170 stations, of which 30 are of the second and third orders. The Central Office forms a station of the first order, as far as circumstances permit.

3. Weather forecasts for the following day have not been officially issued since 1887. But they are always prepared in the Institute and checked from the observations made at 12 stations.

The results of this checking will be found in the Reports of the Director.

In 1896 the success varied as follows:—Wind, between 70 and 88 per cent; weather, between 73 and 80 per cent; temperature, between 83 and 87 per cent. The conditions of weather in the small but mountainous area for which forecasts are drawn are very different.

4 and 5. Pages 2-6 of part iv. of the *Climate of Saxony* contain replies to these questions.

6. The funds placed at the disposal of the Institute yearly by the Ministry of the Interior are at present 45,610 marks (say £2280).

X.—Baden.

Central Office for Meteorology and Hydrography, Carlsruhe.—
Prof. M. Honsell, Director.

1. The Meteorological Service of Baden was founded in the autumn of 1868, under the name of "Central Meteorological Station." The organisation of the same was almost precisely of the pattern of that of the Swiss stations, and was placed under the charge of the then Professor of Physics of the Polytechnic School at Carlsruhe, Hofrath Dr. Wiedemann (now at Erlangen), with the co-operation of Dr. Rühlmann. His successor, Dr. Sohnke, was Director of the Central Station from 1871 to 1882, and after his appointment to the University of Jena the Institute was incorporated with the Chief Office of Waterworks and Highways, with the intention of making the weather observations more useful for the requirements of practical life, especially with regard to water-supply and agriculture. In pursuance of this idea, a closer network of rain-stations was established in 1884, and in the year 1888 a system of snowfall stations was added. Dr. M. Honsell was appointed Director of the "Central Office for Meteorology and Hydrography," and in 1886 Dr. Schultheiss was appointed Director of the Meteorological Branch.

2 At the present time there are in Baden 17 stations of the second order, and 32 rainfall stations; thunderstorm observations are made at 70 places, and snow-depth is regularly recorded at 24 places. There is no regular station of the first order, but at Carlsruhe self-recording instruments for air-pressure, temperature, rainfall, and sunshine are erected. A description of the stations and of their organisation will be found in our Annual Report for 1891, p. 21 *et seq.*

3. Weather forecasts are only made to a limited extent; they do not refer equally to all elements, but only to those in which changes are expected. Their verification in the usual manner is therefore not possible.

4. Among the larger meteorological publications may be mentioned:—*Contributions to Hydrography:* Part 2—"Rainfall Conditions of the Grand Duchy of Baden." In the other parts of the *Contributions to Hydrography* more or less extensive sections on meteorological subjects will be found, as well as in the work, *The Rhine and its Principal Tributaries* (Berlin, 1889), discussed in the Central Office, and published at the Government expense.

5. A new discussion of Part 2 of the *Contributions* is in course of preparation.

6. An exact statement of the whole of the expenses is not possible, as the

cost of the offices, lighting, heating, and attendance, as well as the expense of the library, are borne by the Office of Waterworks and Highways, with which the Central Office is incorporated. It also bears the expense of the Office routine, postage, registration, and accounts.

For each of the years 1898 and 1899 the following sums have been voted :—

	Marks.
For Observers at the Meteorological Stations . .	4220
For Thunderstorm Observations	185
For Weather Telegrams	1180
For Printing of Publications	3080
For other Expenses	800
Total	9465 (say £473)

The personal expenses for the Director, meteorologist, one engineer, draughtsman, and one assistant, amount to about 12,000 marks (say £600).

XI.—Greece.

National Observatory, Athens.—Dr. D. Eginitis, Director.

1. Meteorological observations were organised at the Athens Observatory by the establishment of a station of the second order by its first Director, M. Bouris, in 1847. Prior to that year several observers, viz. Peytier, Bouris, and Fraas, made meteorological observations at Athens, but not officially. The observations were only continued until November 12, 1847. They were resumed on July 13, 1853, by M. Papadakis, who made three observations daily. M. Schmidt continued these observations from the time of his arrival at Athens, December 2, 1858, until his death in 1884. Since that time observations were continued until 1890, under the direction of M. Kokkides.

In addition to the station at Athens, some other stations were established in different parts of Greece, prior to the year 1890, at the expense of the "Parnasse" (a scientific society). The only ones that have worked more or less regularly are Patras, Corfu, and Volos.

In 1890, having been appointed Director of the Athens Observatory, I completed and transformed the station into a Meteorological Observatory, and especially so in 1893, when it was provided with a set of Richard's self-recording instruments. In the same year I established a system of 22 stations of the second order in the provinces, including the three old stations, which were completed and re-established on a new basis. All of these have continued to work regularly under the direction of the Professors of the Lyceums.

2. Each station sends us two telegraphic reports daily—one in the morning, containing the observations of the previous evening and of the morning; and one in the evening, containing observations made at 2 p.m.,—and at the end of each month every station sends a register containing detailed observations for the month. At Athens and in the provinces observations are made thrice daily, at 8 a.m., 2 and 9 p.m. A Meteorological Branch of the Observatory, organised in 1895, undertakes, under my direction, the reduction and publication of these observations.

3. In addition to the telegraphic reports above mentioned, we receive, since 1890, observations from 55 foreign stations in Europe, Asia Minor, and Africa, for the preparation of a Meteorological Bulletin, which is published daily in the newspapers. The publication of a bulletin, with curves and weather forecasts, is in preparation.

4. Since 1890 we have been preparing for publication, in five volumes, the observations made at Athens during 50 years. In the first volume of the *Annales de l'Observatoire d'Athènes*, which has just appeared, we have drawn up

a memoir on the "Climate of Athens." We have also published a "Practical Meteorology," containing instructions and tables necessary for our observers, and in the *Annales* the meteorological observations at Athens for 1895 have been published in detail; also two notes in the *Comptes-rendus* of the Paris Academy of Sciences—one on the "Double Daily Oscillation of Relative Humidity," and the other on the "Rainfall of Athens."

5. We are preparing at present, for early publication in the second volume of the *Annales*, the meteorological observations at Athens for 1896, and those made in the provinces during 1894 and 1895.

6. The budget of the Meteorological Section of the Observatory amounts to 9120 francs (say £380) for the staff and other expenses, exclusive of the salary of the Director, who superintends the three sections of the Observatory.

XII.—Italy.

Central Observatory, Moncalieri.—Count A. C. Vigodarzere, Director.

1. The origin of the Italian Meteorological Society dates from 1859, in which year the Moncalieri Observatory was organised by the lamented Padre Denza. Its operations were increased in 1865 by the establishment of the monthly *Bulletin*, and a further development followed in 1870, with the co-operation of the Italian Alpine Club, and in 1873 the *Bulletin* took the title of the *Italian Alpine and Apennine Meteorological Correspondence.* The name of Italian Meteorological Society was only taken in 1880, and then the Society was organised in the same way as it now remains. The object of the Society is indicated in Chap. II. of the Statutes, which I have the pleasure of sending you. Its present Director, who succeeded Padre Denza, is Count Antonio Cittadella Vigodarzere.

2. The present state of the Society may be seen from the list of stations of the first and second orders.

3. Weather forecasts have never been prepared at Moncalieri.

4. In addition to the complete series of meteorological observations which began with the meteorological year 1865-66, another complete series of researches relating to shooting-stars (since 1869) is carried on. Some observations of atmospheric electricity and of magnetism were made for some years.

5. We have recently commenced actinometric observations and the observation of sun-spots, and have for some time been preparing historical and bibliographical data relating to astronomy and meteorology. An *Annuario storico meteorologico* will be published at the end of this year, and a *Bibliografia generale Meteorologica Italiana* will appear in due time.

6. The Society receives no ordinary subvention from the Government.

XIII.—Netherlands.

Royal Meteorological Institute of the Netherlands, de Bilt, Utrecht.—
Dr. M. Snellen, Director.

1. On December 1, 1848, Prof. Buys-Ballot, in co-operation with Dr. Krecke, made his first meteorological observations in one of the vaults of the ancient walls of the city of Utrecht. They soon put themselves in communication with observers in other parts of the kingdom, and also with foreign meteorologists. Five years afterwards their observations, and especially the publications of Prof. Buys-Ballot, attracted the attention of the civilised world to such a degree that in 1852 the Government took notice of their work, and transformed their humble settlement, by Royal decree of January 31, 1854, into

an official institution, with the title of Royal Meteorological Institute of the Netherlands.

From the beginning Buys-Ballot took much interest in navigation and the benefits to be derived for that branch of social business from observations made on board ship. Consequently the Institute consisted of two sections,—one for observations on land, the other for observations at sea,—each with its own Director. Buys-Ballot was nominated as Chief Director of the whole Institute, Dr. Krecke as Director for the land observations, and a marine officer as Director for the sea observations. After the resignation of Dr. Krecke, Buys-Ballot acted for several years as Section Director, at the same time occupying his position as Chief Director. In the year 1877 this state of affairs was terminated by the nomination of Dr. Snellen as Director of the Section for Land Observations. In the meanwhile several officers of the Royal Navy had been temporarily attached to Utrecht as Directors of the Section for Sea Observations, and in 1872 Baron P. F. van Heerdt (lately deceased) was permanently appointed. The original buildings did not meet the constantly growing requirements of meteorology and its applications. Many years previously Buys-Ballot made proposals for removing to a more suitable locality, but it was not easy to find one, till at length, a long time after his death, an opportunity offered itself in the neighbourhood of Utrecht at "de Bilt," where the Government got possession of a country house and grounds belonging to a large estate, that had been abandoned as such. The dwelling-rooms were fitted up as a meteorological observatory, a library, and offices, whilst on the surrounding grounds two additional buildings have been erected for the purpose of magnetical observations.

2. Besides this Central Observatory, the Institute has under its control 6 stations of the first order, 8 stations of the second order, 7 stations of the third order; 85 stations for rain observations, and nearly 200 stations for thunderstorms.

Besides these stations, dependencies of the Institute have been established in Amsterdam and Rotterdam for the benefit of navigation. Their principal occupations consist in testing all kinds of nautical instruments, regulating compasses, ships' lanterns, and correcting charts for the commercial navy.

3. Each day the Central Office and the dependencies issue weather charts that are delivered free of charge to any one who will pay the postage. These contain forecasts for the next day. An examination test of the percentage of success has never been undertaken, owing to the great difficulty of applying a proper test.

4 and 5. Several investigations have been completed and are now in progress.

6. The Royal Meteorological Institute is wholly a Governmental establishment. The annual grant is, in current money of the Netherlands:—

	Francs.
(1) For Personal Salaries and Clerks' Wages, nearly .	28,000
(2) For Travelling Expenses, Observations at the Outer Stations, Weather Telegrams for Storm Warnings, Repair of Buildings, etc.	18,000
Total	46,000

XIV.—Portugal.

Observatory of the Infante D. Luiz, Lisbon.—Rear-Admiral J. C. de Brito Capello, Director.

1. This Observatory was first built in 1854, at the north-east angle of the ruins of the Polytechnic School, which was destroyed by fire in 1842.

Dr. Pegado, Professor of Physics, after various consultations with General

Sabine, Airy, Welsh, and others, erected a small building, and established the principal standard meteorological instruments of that period: a siphon barometer, with a tube of 19 mm. diameter, by Lerebour and Secretan; an anemograph and self-recording rain-gauge by the same makers; and a standard thermometer, presented by the Kew Committee.

In 1857 magnetic instruments were obtained,—viz. declinometer, dip instrument, and unifilar for horizontal force,—and were erected in a shed in the garden of the Polytechnic School. The magnetic observations were commenced at once.

In 1858 the transmission of meteorological telegrams at 8 a.m. to M. Le Verrier, at the Paris Observatory, was commenced.

The first meteorological stations were Oporto and Campo Maior, established by Dr. Pegado, who left the direction of the Observatory a few months afterwards. The present Observatory was built in 1863, in the centre of the north front of the Polytechnic School building. The magnetic self-recording instruments of the Kew pattern were erected and at work in June 1863. A few months afterwards the photographic barograph and thermograph were also in action.

The construction of the Observatory and the acquisition of the last-mentioned instruments were both due to the Director, Fradesso da Silveira, Professor of Physics at the Polytechnic School. The King, D. Luiz, defrayed all the expenses, 12 million reis (say £1890).

At the end of 1864 there were 10 stations: 7 on the Continent, and 3 at Madeira and the Azores. The directors of these meteorological stations were generally Professors or Doctors, and they received no remuneration. The assistants received £2 a month. The chief object of these stations is the study of the climate, and weather prediction.

The Director, Fradesso da Silveira, died in 1875.

2. At present, the number of stations is 24: 15 on the Continent, of which 4 are of the first order, 7 are of the second order, and 4 are of the third order; 3 in the Azores, of which 2 are of the first order and 1 is of the second order; 1 at Funchal, of the first order; 5 in the colonies, of the first order.

Ten of the stations are subsidised by the Central Observatory. The assistants receive £2 a month. Four of the stations, called international stations, have a second assistant.

All the Continental stations, as well as the Azores, Madeira, and Cape Verde, send meteorological telegrams every morning according to the code generally adopted. At Madeira and the Azores the messages are sent at 7 a.m., and those on the Continent at 9 a.m. They are transmitted to Madrid, Paris, and London. With these telegrams, and those from Spain, France, and England, the daily weather report is compiled.

3. Since December 1, 1864, weather forecasts have been issued for the following day. The percentage of success has never been calculated.

From the same date warnings of storms and bad weather have been issued. The signals used in England have been hoisted at Lisbon and at all the semaphore stations: since 1878 only the "cone" has been used. Since August 1888 a gratuitous service of warnings to ships passing the semaphores on the coast of Portugal has been undertaken. The vessels are warned, by means of the International Code of Signals, of the direction and force of wind, the state of the sea observed at 8 a.m. in the Bay of Biscay, the Straits of Gibraltar, and Madeira. A notice of these signals has been inserted in the International Code.

4. Occasionally memoirs have been published on terrestrial magnetism, atmospheric temperature and pressure, humidity, etc.

5. Nothing in particular: (1) a recapitulation of the mean values of the

meteorological elements from 1856 to 1895; (2) observations for the micrographic analysis of the air, on the system of M. Miguel of Montsouris, twice a month; (3) comparison between the variations of temperature, etc., at Davos-Platz and Serra da Estrella, during 10 years; etc.

6. The present expenses of the Meteorological Service are:—

Observatories and stations of the Continent and Azores:—

Staff	9,328 million reis, say	£1472
Instruments, gas, etc. . . .	1,970 ,, ,, ,,	311
Total . .	11,298 ,, ,, ,,	£1783

N.B.—Only 6 of the stations receive instruments, instructions, etc., from the Central Observatory. The colonial stations are paid for by their respective Governments. The Coimbra Observatory is subsidised by the University.

XV.—Russia.

Central Physical Observatory, St. Petersburg.—General Rykatcheff, Director.

1. The Central Physical Observatory was founded on April 13, 1849, by the Emperor Nicholas I., on the representation of Prof. A. T. Kupffer, supported by Baron A. von Humboldt, and was placed under the Office of Mines, but since 1866 it has been placed under the control of the Imperial Academy of Sciences. Further particulars relating to its original foundation are contained in Vol. VIII. of the *Bulletin de la Classe Physico-Mathématique de l'Académie des Sciences*, Nos. 11 and 12, St. Petersburg, 1850. In 1860 Kupffer had prepared a plan for telegraphic weather forecasting, but he died in 1865 without being able to carry it out. In 1866 he was succeeded by the well-known Meteorologist, Prof. Kämtz, of Dorpat, but that gentleman died before he could realise the plans of Prof. Kupffer. In 1868 Prof. H. Wild was appointed Director. Thanks to his careful administration, the Observatory has attained its present organisation. In 1875 the filial Meteorological and Magnetical Constantin Observatory at Pavlovsk was founded, and was opened 1878, and it may be counted among the chief of the observatories of the world. In 1895 Prof. H. Wild resigned, and was succeeded by General Rykatcheff in 1896.

2. The Central Observatory possesses 4 magnetic and meteorological observatories of the first order,—Pavlovsk (near St. Petersburg), Tiflis (in the Caucasus), Ekaterinburg (on the Ural), and Irkutsk (Eastern Siberia),—over 800 stations of the second order, and 1500 stations of the third order.

3. The daily weather report was published in 1874, and contains weather forecasts. Storm warnings are issued to (1) the Baltic, (2) Black Sea and Sea of Azov. The mean success is as follows:—

Storm Warnings.	Baltic.	Black Sea.
Complete Success . .	80·0 per cent.	72·6 per cent.
Late Warnings . . .	6·2 ,,	11·7 ,,
Failures	13·8 ,,	15·7 ,,
Storms not warned . .	11·6 ,,	16·2 ,,

4. The publication of the results of observations began in 1836, and the detailed observations made under the superintendence of the Administration of Mines were regularly published in the *Annales*, and have been continued in a somewhat altered form down to the present day. From 1869 to 1894, owing to the initiative of Prof. Wild, a *Repertorium für Meteorologie* was published. Since 1894, articles relating to Meteorology and Magnetism have been published in the *Mémoires* and *Bulletins* of the Imperial Academy of Sciences.

5. The following are the present publications:—*Annales* of the Observatory; Monthly Bulletin; Weekly Bulletin; Daily Weather Report; also *Comptes-Rendus* published each year by the Director in the *Mémoires* of the Academy.

6. The expenses of the Service are :—

	Roubles.
For Salary of Government Employees (37 in number) at the Central Physical Observatory	103,720
Other Expenses, including Maintenance of the Provincial Observatories	180,000
Total	283,720

XVI.—Sweden.

Meteorologiska Central-Anstalten, Stockholm.—Dr. R. Rubenson, Director.

1. During the latter part of the eighteenth century, regular meteorological observations were made only at the 3 astronomical observatories at Stockholm, Upsala, and Lund; and, after the formation of the Mannheim Society, also at some of the Swedish colleges, where the observations were taken by the respective mathematical lecturers. At the 3 observatories the observations were carried on also during the first part of the present century, chiefly in accordance with the methods for observation and publication adopted by the Mannheim Society, but without any mutual connection. As this number of stations was much too small in consideration of the extent of the country, and inasmuch as it was very important that the stations to be founded should enjoy a uniform treatment of the materials collected, Edlund, Professor of Physics at the Royal Swedish Academy of Sciences, organised, in the year 1859, a system of a larger number of stations, of which he himself took the lead. The observations at these stations were published in the work *Meteorologiska Iakttagelser i Sverige*, of which the first series, except the last years, was edited by Edlund himself.

However, since the opinion had become general, that for the development of Swedish Meteorology a special institution was required, with a director specially working in this science, the State erected a Meteorological Central Institute, which was placed under the care and supervision of the Royal Swedish Academy of Sciences, and was charged with (*a*) the direction of the meteorological stations, and their supply with instruments and blank forms (the inspection journey is made by one of the officials of the Institute, appointed to it at each time by the Royal Academy of Sciences); (*b*) to reduce the observations made at the meteorological stations, and to publish them in the *Meteorologiska Iakttagelser i Sverige* (2nd series, since vol. xv., 1873), the printing of which work is paid for by the Academy of Sciences ; (*c*) to organise and keep up the daily weather service founded upon inland and foreign meteorological telegrams, to compile by means of these telegrams daily synoptic charts, to make a summary of the weather throughout the northern part of Europe, with forecasts for the next day, and to communicate these by wire to places and corporations which have been entitled thereto by subscription at the telegraphic administration ; (*d*) to communicate to the official authorities, at their request, any information as to which the Institute possesses the requisite materials; and (*e*) to follow attentively the advances of Meteorology, and by his own labours to endeavour to contribute to its development.

Dr. R. Rubenson has, since its first establishment, been the Director of the Meteorological Institute.

For Nautical Meteorology there was instituted, in the year 1878, a special Office, named "Nautisk-Meteorologiska Byrå," having a special direction consisting of the Chief of the Hydrographical Surveying Office and the Directors of the Central and the Nautical Meteorological Offices. The last has, since the time of its establishment, been directed by the Commodore, F. G. Malmberg. This

office administers the observations from vessels at sea, from the lighthouses along the coasts of Sweden, and from the stations on the sea-coast and the coasts of the lakes, and is engaged with the investigation of questions relating to the adjustment of compasses.

2. Our country possesses only 1 station of first order, viz. the Meteorological Observatory at Upsala, belonging to the University of that city, and exercising its functions independently of the Central Institute. At this station the service commenced in the month of June 1865, when hourly observations were established under the direction of Dr. Rubenson. These observations were in August 1868 exchanged for those of the recording instruments. Since 1873 Prof. H. Hildebrandsson has been Director of this station of the first order. Its observations are published in the work *Bulletin météorologique mensuel de l'Observatoire météorologique de l'Université d'Upsal.*

The number of stations of second order supplied with barometer, dry and wet bulb thermometers, maximum and minimum thermometers, rain-gauge, and wind-vane, where the regular observations are made three times daily, at 8 a.m., 2 and 9 p.m., was, at the end of the year 1897: (*a*) stations paid for by the Government, 34; (*b*) private stations, 10.

The number of stations of third order, all private, where rain, snow, and hail are measured daily at 8 a.m., and at some of which also the temperature is observed, was, at the end of 1897, 341.

The number of stations of fourth order, where some of the following phenomena are noted, viz. the thunderstorms, the freezing of the lakes and breaking up of the ice, and the periodical phenomena in the vegetable and animal kingdoms are observed, was, during the year 1897, 151.

3. Following the indications of the daily synoptic charts—which in the summer are drawn up twice daily, viz. before 1 p.m. two charts representing the weather at 9 p.m. and at 8 a.m., and before 6 p.m. a chart of the weather at 2 to 4 p.m., and during the remainder of the year only once daily, at 1 p.m. —a summary of the weather in Northern Europe is worked out, together with forecasts for the next day.

A regular abstract showing the agreement of the forecasts with the following weather has not been made hitherto, but occasional comparisons have shown that the percentage of success is about 80 for the rain and snow, but for the other meteorological elements the matter has not yet been sufficiently examined.

4. A number of discussions, based upon observations collected by the Meteorological Institute, have been published by Messrs. Arrhenius, Edlund, Ekholm, Fagerholm, Forssman, Hamberg, Hjeltstrom, and Rubenson.

5. Several investigations are now in progress.

6. The Government grant for this year (1898) amounts to Kr. 34,300 (about £1900), for the purpose of defraying the following expenses:—

	Kr.	Kr.
Appointment of the Director	6000	
Appointment of the Clerk (Amanuensis)	3000	
Salary of the First Scientific Assistant	2400	
Salary of the Second Scientific Assistant	1500	
Salary of the Observers in the Provinces	7800	
		20,700
For Calculations and other Expenses of the Bureau		13,600
Total		34,300

XVII.—NORWAY.

Norske Meteorologiske Institut, Christiania.—Dr. H. Mohn, Director.

1. The Meteorological Institute of Norway was founded in 1866. Its Chief has from that time till now been Prof. Dr. H. Mohn. It belongs to the

University of Christiania. It is charged with the study of the weather, the climate of Norway, storm and weather warnings, collection of meteorological observations from the northern and arctic seas, publication of observations and results.

2. It has now 3 stations of the first order, 40 stations of the second order, 36 of the third order, and 351 rain-gauge stations.

3. Storm warnings have been sent to the Norwegian coast south of Bodö since 1869. From the same time daily weather forecasts have been published for Christiania through the papers, and posted up in a convenient place. Since 1883 weather warnings for agricultural purposes have been sent daily from Christiania, in the months of July, August, and September, to the districts about Christiania. In 1897 these were extended to the valleys of Valdres, Gudbrandsdalen, and Osterdalen. The percentage of success (for precipitation) has been about 85 to 90.

4. A list of completed investigations would comprise climate, oceanography, thunderstorms, arctic geography, weather studies, iridescent clouds, fog-signals, and other subjects belonging to terrestrial physics.

5. The regular publications are: *Jahrbuch des norwegischen meteorologischen Instituts.* "The Temperature and Precipitation in Norway" (in Norwegian) for each year. *Klimatabeller for Norge.* Temperature, pressure of air, humidity, wind, published. To be continued.

6. The ordinary grant from the Storthing is about £2000 (Kroner 36,000).

XVIII.—Switzerland.

Central Anstalt für Meteorologie, Zürich.—Dr. R. Billwiller, Director.

1. So long ago as 1824 the Swiss Society of Natural Philosophy possessed a small network of 12 meteorological stations. The superintendence of this organisation was entrusted to a Committee, at the head of which was first Pictet, and after his death Hofrath Horner. This undertaking had to be given up in the year 1837, chiefly owing to want of uniformity of superintendence and to lack of funds. In 1863 that Society established a new Meteorological Service of over 80 stations, and it was supported financially by the Federal Government and the Cantons. The organisation and superintendence of the observations were again undertaken by a Committee (*Meteorologische Kommission der schweizerischen naturforschenden Gesellschaft*). The President was first the Physicist, Prof. Mousson, and afterwards Prof. R. Wolf, Director of the Federal Observatory at Zürich; and the organisation was located at that Observatory, to which the collection, reduction, and publication of the observations were relegated. These duties were performed first by one, and afterwards by two, assistants, under the supervision of the President. Gradually the activity of the Committee became reduced, and the work was almost exclusively carried on by the Office, which also conducted the central meteorological station at Zürich. The yearly subvention of the Bund increased gradually from 11,000 to 15,000 francs. The Cantons had only contributed to the cost of establishment. As, in the course of time, the meteorological data obtain a constantly increasing importance for affairs of ordinary life, and the public required the issue of weather reports with forecasts for the benefit of agriculture, the Federal authorities thought it right to establish an official meteorological office, and by decree of December 23, 1880, the Swiss Meteorological Central Office was created. Dr. Billwiller, who had for some years superintended the duties of the Zürich Meteorological Office, was appointed Director. The new institution was completely separated from the Swiss Society of Natural Philosophy, and placed under the Ministry of the Interior, with a superintending committee called the Federal Meteorological Committee.

The President of the latter body is the present Chief of the Department (Member of the Federal Council). Prof. Wolf, who was President of the former Committee, acted as Vice-President up to the time of his death in 1893.

2. The principal duty of the new establishment was the investigation of the climate of the country; and subsequently, since 1881, the practical interests of the public were attended to by the publication of a daily weather report. The forecasts, added with all reserve to the weather reports, have had the following success in recent years:—70 per cent complete success; 25 per cent half success, viz. cases in which the forecast was not correct in respect of one or two elements; 5 per cent total failures. It should be noted that the forecasts refer mostly to temperature, rainfall, and the character of the weather, and only rarely to the wind, which is generally light in our country, and depends entirely on, or is modified by, the local configuration of the land.

3. There are 4 stations of the first order (including the Säntis, 2500 metres high), 102 stations of the second order (3 observations daily), 9 stations of the third order (temperature and rain only, 3 observations daily), 197 rainfall stations. Total 312. The number of rainfall stations will be increased by about 100 in the next year or two, in order to meet practical requirements. The numerous river observations which are undertaken in the country require an exact calculation of the amount of the flow at flood-water, which can only be carried out by increasing the number of rainfall stations, to which may be added the continually increasing technical use made of the water-power of the country.

4. Among the climatological works, the following are nearly completed:—Climatological tables for all stations, with 30 years' means (1864-1893), in which the data for stations where the observations are incomplete will be reduced as far as possible to the 30 years' period. The tables will probably not be published before 1900, after the observations made this year shall have been included and new means calculated.

5. The materials and tables are being discussed with the view to a detailed climatology of the country. Also special investigations relating to the periodical winds of the greater valleys; on the influence of height above sea and topographical conditions on the rainfall; on the influence of local peculiarities of the ground on the weather of different parts of the country; and on the influence of the Alps, as a whole, on climate and weather of the country.

6. The annual vote made to the Institute by the Government was at the time of the establishment (1881) 25,000 francs; this has been increased at various times and now amounts to 55,000 francs. Receipts from other sources amount to about 4000 francs.

XIX.—Hong Kong.

Observatory.—Dr. W. Doberck, Director.

1. The meteorological organisation which I direct was founded by myself, under instructions from the Government, in 1883.

2. There is only 1 first order station: the Hong Kong Observatory. There are 40 second order stations. There are 35 telegraphic reporting stations. There are 10 third order stations, which are also telegraphic reporting stations, so that the total number of land stations is 66.

3. The percentage of success of weather forecasts is 96; the percentage of success of forecasts of gales and high wind caused by typhoons is 83.

4. In 14 annual volumes of *Observations and Researches* a full investigation of the meteorology of Hong Kong has been published. During 15 years over 250 typhoons have been investigated and the results published in the annual volumes, and also in my pamphlet *On the Law of Storms in the Eastern Seas.*

5. Similar investigations are in progress now, but it is nearly certain that hourly observations made in future will contribute little further information, and also that discussions of local observations, as observations recorded in log-books during typhoons, will not lead to further discoveries concerning typhoons. These problems have been exhaustively investigated.

6. The amount of grants from the Government is about £1500 a year, but the Eastern Extension and the Great Northern Telegraph Companies furnish gratuitously telegrams, the cost of which (if paid for) would be upwards of £50,000 a year.

XX.—India.

Meteorological Office, Calcutta.—Mr. J. Eliot, F.R.S., C.I.E., Meteorological Reporter.

1. The commencement of the work of meteorological observations in India dates from about 1864. Previously to that, meteorological observations had been systematically recorded at observatories in Madras, Bombay, and Calcutta, and valuable observations for short periods had also been taken at Simla, Dodabetta, and Trevandrum—the first under the direction of General Boileau, and the third, at Trevandrum, under the direction of J. Allan Broun. The last-named Observatory was maintained by the Maharajah of Travancore, and the others by the East India Company and its successor, the Government of India.

In addition, meteorological observations, chiefly of temperature, wind, and rain, were recorded at many of the hospitals and dispensaries. The instruments were untested and very unsatisfactory, and the observers in many instances were not supervised, and were hence exceedingly careless; and the observations were not only in most cases of little value, but frequently tainted with glaring errors. Many of these series of observations were utilised in the Report of the von Schlagintweit's Scientific Mission to India and High Asia, in which no attempt was apparently made to discriminate between accurate and inaccurate observations.

The first steps to initiate a general system of meteorological observations and investigations were taken by Col. R. (now Sir Richard) Strachey. He called the attention of the Asiatic Society to the need for systematic observation, and of a controlling person to direct the work of the observers. A Committee was formed, but it was not until 1864 that it drew up a report which was submitted to Government. The Society was then required to draw up a scheme to give practical effect to its recommendations. The scheme, as presented to Government in the beginning of 1864, was published in the *Proceedings of the Asiatic Society* for December 1864. The scheme (which was probably chiefly the work of Sir R. Strachey and Mr. Blanford) was, in its main features, similar to that which was finally introduced in 1875.

Whilst this scheme was being considered, the great Calcutta cyclone of 1864 occurred. It directed the attention of the public and Government to the need of a meteorological system for the purpose of warning the port of Calcutta of the approach of cyclones.

About the same time the Secretary of State urged the necessity of systematic meteorological observations in connection with the requirements of the Sanitary Commission. The Government of India referred the matter to that Committee, who recommended the system of Independent Local Reporters for the Punjab, the North-Western Provinces, and Madras. Meanwhile, in Bengal, a local committee had been formed to initiate and carry out a system of storm warnings, and in 1867 a Provincial Reporter was also appointed for Bengal.

The following gives the names of the Reporters from 1864 to 1875, when the next great step was taken in the development of meteorological observations in India:—

Province.	Reporter.	Appointed.
Punjab	Dr. A. Neil	April 1865
North-Western Provinces .	Dr. M. Thomson	February 1865
	J. Eliot	November 1874
Madras	N. R. Pogson	May 1867
Bengal	H. F. Blanford	April 1867

The Provincial Reporters issued annual meteorological reports of their respective provinces. The defects and evils of this system of limited independent fields of investigation are almost self-evident. No information was available for the greater part of India, and it was impossible to bring together the data for the provinces which had meteorological systems so as to obtain a correct and accurate view of the meteorology of India as a whole. Sir R. Strachey called attention to the defects of the system, and finally it was decided to imperialise the work by combining the provincial systems into a single organisation under the control of a General or Imperial Reporter, and to extend the field of observation over the whole of India.

Mr. Blanford, the Meteorological Reporter to the Government of Bengal, was therefore requested in 1874 to draw up a scheme in accordance with these orders. The most important proposals of this scheme were:—(1) The appointment of a Meteorological Reporter to the Government of India to superintend and control the consolidated system of meteorological observations in India. (2) The appointment of Provincial Reporters or officers to control the work of meteorological observations in the provinces, and in which the work had not been systematically arranged. (3) The establishment of a Central Observatory at Alipore (Calcutta), part of the work of which was to be the testing of all instruments issued to observatories in India. (4) The adoption of common methods of observations, and the record of observations in all parts of India. (5) The systematic study of the meteorology of India as a whole.

Mr. Blanford's scheme was approved and sanctioned, and he was appointed Meteorological Reporter to the Government of India, with instructions to carry out his scheme.

Mr. Blanford was Meteorological Reporter from 1875 to 1887. He devoted himself chiefly to the extension of the field of observation, the improvement of the methods of observation, and the accumulation of data for the discussion of the climatology of India. In addition to the annual *Reports on the Meteorology of India*, he initiated the publication of the *Indian Meteorological Memoirs*, to contain the more important investigations of the Meteorological Department. Three volumes containing 20 memoirs were issued during his directorship, the most valuable being his own contribution on the *Rainfall of India*.

His successor is Mr. J. Eliot, previously Meteorological Reporter to the Government of Bengal.

During his directorship the Government, as well as the public, have become increasingly alive to the value of early meteorological information, and of storm and flood warnings and seasonal forecasts. Hence, while the accumulation of accurate data and their discussion continues to form the most important part of the work of the Department, progress has been chiefly shown in the newer fields of meteorology. In order to give early information, daily weather reports, each illustrated with charts, are issued from the Simla, Calcutta, Madras, and Bombay Meteorological Offices. The system of storm warning has been largely extended. Originally the storm-signals were only hoisted at a few of the largest ports. Now all ports are warned, including the smaller ports frequented only by native craft, and methods have been introduced for communicating the latest information of the weather over the whole Bay area to vessels at the larger ports by hoisting flags. Warnings of the probable occurrence

of storms and floods are given to a large number of Government officers in the Railway, Irrigation, and Public Works' Departments in order that they may take timely precautions to minimise the damage to property. Weather information or forecast is also given systematically to the officers commanding frontier expeditions to assist them in arranging for their movements with the least inconvenience to the troops. In this case every effort is made to give as long a forecast as possible of the probable continuance of fine weather, or of the approach of rainy or stormy weather. Similar weather forecasts are also given to indigo-planters in Bihar through one of the largest agencies in Calcutta; and an attempt has been made to give forecasts to tea-planters, but hitherto with little success, in consequence, partly, of the difficulty in distributing the information locally.

Another important feature of the past ten years has been the extension of the field of observation. A number of observatories have been opened in Persia, and daily weather telegrams are received during the whole year from two stations in the Persian Gulf, and during the winter from Teheran and Ispahan. These enable early warning, extending to two or three days, to be given of the approach of cold weather, storms, or of cold waves to North-Western India. Similarly, additional observatories have been established at insular stations in the Indian Seas and Indian Ocean, and weather telegrams are received from these stations during a part of the year, showing the advance and variations in the strength of the South-east Trades, and their extension, the South-west Monsoon winds. Finally, a *Daily Report and Chart of the Indian Monsoon Area*, including the whole of the available data collected from ships entering the ports of Bombay, Calcutta, and Rangoon, as well as of all the land observatories under the Department, is prepared and published about three months after date. This gives a connected history of the current meteorology of the whole Monsoon area, and has already thrown much light on the progress and variations of the South-west Monsoon winds and rainfall.

2. There are 227 observatories working under or co-operating with the Meteorological Department, which are classified as follows:—9 first class, 70 second class, 143 third class, 5 fourth class. There are also 2462 rain-gauge stations.

3. Weather forecasting has not been carried on in the way in which it is conducted in Europe, in consequence partly of the slowness of communication, and partly of the state and education of the great body of the people, including nearly the whole of the agricultural population. What may be termed special forecasts are issued, whenever considered necessary or advisable, to (1) special classes, as, for example, sailors, the commercial and mercantile classes of the larger ports, and indigo-planters; (2) special officers of Government, as, for example, district officers, public works officers in charge of important works, officers in charge of canals, and railway officers in districts liable to floods; (3) military authorities when any expedition is in the field on the North-West Frontier, etc. These forecasts include (1) storm warnings, or warnings by means of storm-signals, of the approach of cyclonic storms; (2) warnings of the probably early occurrence of floods likely to damage railways, canals, or other public works; (3) forecasts of the probable weather from 24 to 48 hours ahead, chiefly for the military authorities.

Finally, for the information chiefly of the Imperial and Provincial Governments and district officers, and the public generally, seasonal forecasts are regularly issued. These are at present:—(1) Forecast issued in the first week of June of the probable distribution of the rainfall of the months of June to September. (2) Forecast issued usually in the first or second week of August, stating chiefly the probable effect of any abnormal snowfall which may have occurred in June and July in modifying the distribution of rainfall during the

remaining monsoon months. (3) Forecast issued in the first or second week of December, stating the probable character and distribution of the winter rains in Northern India, and of the winter snowfall in the North-Western Himalayas (from December to the end of February). (4) Special forecasts are also drawn up for the information of Government at their request, whenever conditions appear to be doubtful or critical over any considerable area.

4. No attempt has been made in India to measure the success of the work of forecasting by means of percentages, partly because it is considered more or less fallacious, and partly as the methods and conditions of forecasting in India differ from those in Europe or North America, and hence any comparison by percentages or otherwise would probably be fallacious and misleading.

5. The following is a list of investigations in progress:—(1) Discussion of the air movement over the North-Western Himalayas as indicated by anemographic observations taken at Simla; (2) observations recorded during the solar eclipse of January 22, 1898, with a discussion of the chief results; (3) thunderstorms at 10 selected stations in India, with a discussion; and (4) discussion of the hourly observations recorded at Augustia and at certain stations at different elevations near Trevandrum during the years 1856-64.

6. The amount sanctioned by the Government of India for the Meteorological Department is Rs. 331,610, or in sterling at the present rate of 1s. 4d. £22,100 practically. The chief features of the expenditure are, roughly, half a lakh for the observatory establishment; half a lakh for the clerical establishment in the seven meteorological offices in India; half a lakh for the reporters who discuss the observations, carry out all the investigations, and issue warnings; and nearly a lakh and a half for the weather telegrams received and issued. As the telegraphic lines are the property of Government, this is nominal, and appears as earnings in the accounts of the Government Telegraph Department.

XXI.—Java.

Observatory, Batavia.—Dr. van der Stok, Director.

1. In 1856 Alexander von Humboldt represented to the Governor-General of Netherlands India, the Chev. F. Pahud, who, on his way to India, visited Berlin, of what great value a magnetical and meteorological observatory at Batavia would be for the promotion of knowledge concerning terrestrial magnetism and meteorological phenomena between the tropics.

The letter was sent to the Minister for Colonial Affairs at the Hague, who forwarded it for advice to the Royal Academy of Sciences at Amsterdam. The Academy strongly supported von Humboldt's suggestion, and invited its member, Prof. Buys-Ballot, to draw up a plan.

In 1857 Prof. Buys-Ballot submitted to the Academy a plan comprising: (1) the erection of a magnetical and meteorological observatory adapted for hourly observations at Batavia; (2) the organisation of meteorological stations of the second order at a few other places in the East Indian Archipelago; (3) a magnetic survey of the Archipelago in connection with the magnetical observations at Batavia.

In 1859 Dr. P. A. Bergsma was appointed director of the observations to be made in Netherlands India, and was commissioned to study the different systems of instruments then used in Europe, especially at the Kew Observatory. Dr. Bergsma was instructed in the use of instruments and the management of an observatory.

In 1862 Dr. Bergsma arrived in Java, but, owing to difficulties encountered in obtaining a well-situated building and to the necessity of training Javanese assistants before commencing the regular observations, hourly readings of

barometer, thermometers, wind, rain, and magnetic declination were not commenced till January 1, 1866. These hourly meteorological observations have been continued without interruption up to the present time.

In 1875 the Observatory was officially established, and Dr. Bergsma appointed its first Director.

In 1876 Dr. van der Stok was appointed Sub-Director, after having visited different observatories in Europe; and in May 1877, on his arrival in Java, the various buildings for the establishment of a magnetograph and other self-registering instruments were nearly finished.

In 1879 Dr. Bergsma organised a system of rain observations throughout the Archipelago. A plan for the erection of meteorological stations of the second order, in 1880, submitted to Government, was rejected on account of the great cost.

In 1882 Dr. Bergsma resigned his position and started for Europe, but died on board ship in the Red Sea.

In 1882 Dr. van der Stok was appointed Director; and in 1884 the new Sub-Director, Dr. S. Figee, arrived in Java.

2. The personal establishment consists of a Director, a Sub-Director, a European computer, and twelve Javanese assistants.

Rain observations are received from 213 stations.

Tidal observations are made at 3 stations by means of self-recording instruments, and at about 80 stations thrice daily.

Wind observations, made thrice daily by different non-official observers, are received from about 85 stations.

The annual publications are :—

(1) *Observations made at the Magnetical and Meteorological Observatory at Batavia.* Of this work the 20th volume, 1897, is nearly printed. Summarising tables are given after every five-year period.

(2) *Rainfall in the East Indian Archipelago.* The 19th volume, 1897, is nearly printed.

3. As the different islands of the Archipelago are situated out of the region of cyclones and typhoons, barometric observations are of importance from a scientific point of view only, and of none whatever for immediate practical purposes.

Telegrams containing information about meteorological elements are daily sent to Adelaide, Australia.

4. The completed investigations have been: (*a*) "The influence of the moon on barometric pressure and amount of clouds"; (*b*) "The influence of the moon on magnetical elements"; (*c*) "An inquiry into the alleged 25·8 day period on barometric and magnetical elements"; (*d*) "A work entitled *Wind and Weather, Currents, Tides, and Tidal Streams in the East Indian Archipelago*"; (*e*) As the complete magnetic records extend over more than 14 years, and have been fully worked out, this investigation may be considered to be completed with regard to many questions, as diurnal variation, relation to sun-spots, etc.; and (*f*) An inquiry concerning the best climatological and hygienic conditions to be found in Central Java, with a view of erecting barracks for troops in a cool climate.

5. The investigations now in progress are: (*a*) during two years cloud measurements have been made by means of eye-observations and photogrammeters simultaneously from two pillars at a distance of 1625 metres, the corresponding points on the negatives have been measured off, and a great many of the calculations have been made; (*b*) the intensity of the daylight and the illumination of different parts of the sky, as measured by means of a photometer of Weber's pattern; (*c*) the calculation of tidal constants for those places where the tides are not yet known with a sufficient degree of accuracy.

6. The Observatory is placed under the control of the Commander of the Fleet; the expenses merely are provided by Government, and amount to about £3000 a year.

XXII.—New South Wales.

Observatory, Sydney.—Mr. H. C. Russell, F.R.S., Government Astronomer.

1. In 1821 Sir Thomas MacDougal Brisbane arrived in Sydney as Governor of the new Colony, bringing with him a set of astronomical instruments, and founded an astronomical observatory at Parramatta, a town 14 miles west of Sydney and at the head of the navigation of the Harbour. Meteorological instruments are not mentioned, but it appears in the records that barometer, temperature, and rain records were made at that observatory rather intermittently in later years, but the barometer and temperature records have disappeared. Rain records from 1830 to 1838 were given in an official report. Rain records from November 1822, all 1823, and 1824 up to end of March, are extant, thence to 1830 no record.

In 1841 it appears that instructions were sent out, and officers told off to carry out magnetic observations in Tasmania; and at the same time meteorological observatories were established at Sydney, Brisbane, Port Macquarie, N.S.W., Melbourne, and Hobart. The record was carried on at Sydney (South Head, 5 miles east of the town) up to 1855. Then the record suddenly ceased by the departure of the observer to New Zealand. Fortunately, Mr. Stanley Jevons, then in the Sydney Mint (afterwards known as Prof. Jevons), had begun taking meteorological observations in Sydney for his own information, and he carried on the work until Sydney Observatory was established in 1859. His work, fortunately, made a continuous record from 1841 to the present time for Sydney. That at Brisbane lasted seven years; that at Port Macquarie up to September 1852; that in Melbourne to the end of 1852; that at Hobart has been continuous since 1840.

About 1856 Sir William Denman, then Governor of New South Wales, induced the Government to establish an observatory at Sydney, for which, at the time, all the astronomical instruments that had been at Parramatta Observatory were available, and the Government built the present Observatory in the heart of Sydney on Flagstaff Hill. An astronomer was to be obtained from England, and the selection left to Sir G. B. Airy, Astronomer Royal, who was also to instruct the new astronomer what he was to do. He selected the Rev. W. Scott, who commenced his duties in November 1856. The part of his duty with which we are at present concerned was the order that he was to establish 12 completely equipped meteorological observatories in New South Wales, which at that time included what is now Queensland.

In 1859 Mr. H. C. Russell was made assistant to Rev. W. Scott, and the meteorological and astronomical work was carried on until 1862, when the Rev. W. Scott resigned, and Mr. Russell was appointed acting astronomer, and he held the office until the arrival, on January 7, 1864, of Mr. G. Robarts Smalley, the newly appointed astronomer. At this time the stations originally established by Mr. Scott were all in full work. During Mr. Smalley's continuance in office, the meteorological work was allowed to fall off, and at his death in August 1870 there were only 5 meteorological stations in New South Wales. Mr. Russell was then appointed astronomer, and he at once began the extension of the meteorological and astronomical duties of the staff in Sydney Observatory. At that time it consisted of the astronomer, one assistant, one youth, and a caretaker. At the present time the staff consists of the astronomer and three astronomical assistants, four assistants for general meteorology, three assistants for weather chart service, an instrument maker, a caretaker, and two

boy messengers—15 in all. In 1875 Mr. Russell had leave given to him to visit the observatories in Europe and America, and he availed himself of the opportunity to visit and see how the meteorological services of England, France, and America were carried on. Upon his return to Sydney, he began to publish a weather chart in the *Sydney Morning Herald*. The chart used included South Australia, Victoria, New South Wales, and Queensland, and was made up on a type-metal block so designed that the weather at the various stations could be set up in ordinary type. This was done at the Observatory, and the printing was from a stereotype of the chart. Some attempts were made at forecasting, but at that time the observing stations were generally too few, especially in the back country and in Queensland.

In 1879 an International Exhibition held in Sydney gave Mr. Russell the opportunity, and at his instance the Government called together a Meteorological Conference in Sydney. New Zealand, Victoria, South Australia, and Sydney were represented. The meteorologist at that time in Queensland was unable to attend. The result of the Conference was a decided improvement, and a more complete accord, in carrying out the meteorological service of Australia. The question of high-level stations, then creating some interest in Europe, was discussed, and it was resolved to establish one in each colony as soon as possible; and the establishment of a station at Kiandra in New South Wales, at an elevation of 4600 feet, was the result of that resolution. But the most important result of the Conference was the improvement in the intercolonial exchange of telegrams between the colonies of South Australia, Victoria, New Zealand, and New South Wales, and the facilities acquired for studying the weather closely; and this paved the way to the issue of forecasts in Sydney in 1887.

2. At the time of the Conference in 1879 New South Wales had in all 152 meteorological stations; of these, 21 were first class stations, 50 second class, and 81 rain stations. These numbers have steadily expanded, and now (1898) we have 192 stations reporting weather by telegram twice a day; of these, 31 are first class, 65 second class, and the remainder simply report wind and weather.

3. At 8.30 a.m. all the readings of instruments, rivers, etc., are sent in with the general reports of winds and weather. At 3 p.m. all the stations again report wind and weather; at 6 p.m. 26 first class stations send in full reports of instruments and weather; and at 8.30 p.m. 27 selected stations on the coast (harbours, lighthouses, etc.) report winds, weather, and sea.

From the other colonies we receive as follows:—Victoria sends 9 a.m. readings from 14 first class stations, and again at 3 p.m. from 8 stations; South Australia sends in 9 a.m. readings from 23 first class stations, that is once a day; Western Australia sends all readings from 21 first class stations once a day; Tasmania from 8 first class stations once a day; New Zealand from 3 stations once a day; Queensland sends once a day from 25 first class stations, and from 57 wind and weather stations; and New Caledonia sends weather from 2 stations. We thus receive, all told, 594 weather telegrams each day, Sunday excepted. These are so divided as to time that we use 343 for the forenoon chart, which never includes Western Australia, and very often not Tasmania. For the afternoon chart, which is really the completion of the day's chart, we receive 254 telegrams. This enables us, at the same time, to make a new map of New South Wales at 6 p.m. and Victoria at 8 p.m., and get the data for a 9 p.m. forecast, which is posted in conspicuous places for the use of shipping at 9.20 p.m., and published in the early morning papers. We print 15 copies of the morning chart for local wants, and 50 copies of the 9 p.m. chart for exchanges.

With regard to the question of forecasts, many careful observers outside, *i.e.* the public, say that we are always right. We claim a percentage of 90 successful forecasts. To an English or American forecaster this may seem absurd, but it is

nevertheless true, and our greatest success is due to the comparative (that is as compared with the United States and Great Britain) simplicity and regular sequence in our weather changes.

4. The published investigations are few:—"Moving Anticyclones," "Southerly Bursters," and "Types of 20 Australian Phases of Weather." For use in forecasting we have a number of others, not published.

5. The amount of the money grant is £2240, of which £470 is for salary of observers in the country,—one at £50 per annum and 35 at £12 per annum,—and for salaries in Sydney £1335 (this includes half my own salary, which I divide between Astronomy and Meteorology).

XXIII.—Queensland.

Weather Bureau, Brisbane.—Mr. C. L. Wragge, Government Meteorologist.

1. The Government of Queensland, in January 1887, established a Meteorological Bureau as a branch of the Post and Telegraph Department of the Colony. The work of organisation and management was entrusted to Mr. Clement L. Wragge, who was appointed Government Meteorologist. He based his plan of action on the lines adopted by the Meteorological Office, London, and the Chief Signal Office, Washington, while yet working in strict accordance with the rules of the Royal Meteorological Society. The work now covers not only Queensland, British New Guinea, New Caledonia, and the South Pacific Islands, but the whole of Australasia and New Zealand, by a system of intercolonial exchange.

2. The number of stations is:—23 first order; 47 second order; 93 climatological; 464 rainfall.

3. Forecasts for all Australasia were initiated in 1887-88. The percentage of success for all Australasia averages now 90 to 93.

4. The principal work consists of, and has been, in addition to the forecasts and weather charts, investigations of local climate with reference to Queensland only, including particularly temperature, humidity, and rainfall; and in investigating the question of the most suitable height for rain-gauges. We have found that a height of one foot above the surface of the ground will not answer for Australasia, because (*a*) in parts of the tropical coast grass grows too rank and too quickly to be always kept under, especially when observers, who are also officers of the Post and Telegraph Department, are absent on line duty. In such circumstances the grass will overlap the gauge, and the instrument—which is capable of holding 26 inches without overflowing—is, under these circumstances only, read on the return of the officer (in all other cases the gauge is read of course at 9 a.m. daily). (*b*) In far western Queensland, during times of drought the ground bakes thoroughly hard; and when the first thunderstorms come, accompanied by heavy squalls, the rain re-splashes from the ground and is blown into the gauge if only at a height of one foot. Therefore we have placed all our gauges in Queensland at the new standard height of two feet above the ground; and I recommend this plan as a uniform standard for all Australasia, including New Zealand.

By means of the daily weather charts we have thoroughly investigated the characteristics and courses of the anticyclones, cyclones, and V-shaped disturbances.

5. The before-mentioned investigations are of course still in progress. Further, we are discussing and rapidly preparing for publication data secured at the new mountain station on the summit of Mount Kosciusko (7328 feet), and at the co-relative low-level stations at Merimbula near Eden in New South Wales, at Sale in Victoria, and at Sydney; also the data from Mount Wellington

and Hobart in Tasmania. The results from all these stations, though outside our colony, nevertheless form a special part of our work.

6. The annual grant varies from £1600 to £1650.

XXIV.—South Australia.

Observatory, Adelaide.—Sir Charles Todd, K.C.M.G., F.R.S., Government Astronomer.

1. The meteorological organisation was started by me soon after my arrival in the colony in November 1855, I having accepted the appointment of Observer and Superintendent of Telegraphs. Observations were commenced at Adelaide in November 1856, and have been regularly continued to the present date. For some time they were all made by myself, as I had no assistant. In 1872 and 1873 the Observatory Buildings and Transit Room were erected, and the Equatorial Building in the following year, the telescope being mounted and adjusted just in time for the Transit of Venus (December 1874).

2. The Observatory at Adelaide is the only station with self-recording and other instruments necessary to constitute it a first class station, as defined by the Meteorological Conference at Vienna; but the barograph and thermograph want a suitable house to be erected before they are brought into use. In addition, we have 22 well-equipped stations of the second order.

At Port Darwin, Alice Springs, Cape Borda, and Cape Northumberland, observations are made every three hours, day and night, of barometer, temperature, wind, and weather. At Daly Waters, Eucla, Fowler's Bay, Streaky Bay, and Port Lincoln observations are made at 9 a.m., noon, 3 p.m., 6 p.m., and 9 p.m., of barometer, temperature, etc., except Fowler's Bay, which is only a barometer station, and at other stations at 9 a.m., 3 p.m., and 9 p.m.

Rain-gauges are kept at nearly every telegraph station in the colony, and wherever it may be thought desirable to place a gauge the Department lends one to any suitable person who will take charge of it, on condition that accurate returns are furnished monthly to me. Besides these, many persons provide their own gauges, and kindly assist by sending me their records.

In 1870 we had 46 stations, in 1883 we had 254 stations, in 1898 we had 450 stations.

3. Since October 1888 weather forecasts have been issued daily at 1 p.m. to cover the weather probable during the night and next day (from 6 p.m. till 6 p.m.), based on reports taken at 9 a.m. over Australasia. The percentages of success for the 10 years 1889-98 have been: verified 75, partially or nearly correct 19, and failure 6.

The forecasts are wired to every telegraph office throughout the settled districts, and are much appreciated by the farming industry.

Besides the daily weather forecast, a special forecast has for some months past been supplied each week to the outgoing mail steamer of the probable weather during the run from Largs Bay to Albany (3 days). We have not verified these; but I do not think there has been a single failure to date.

4. Since 1875 the meteorological results have been published annually in considerable detail, with explanatory charts and rainfall maps. With the 1896 volume a mean rainfall chart of the Colony has also been issued: 1897 is now in the printer's hands.

A number of very full reports are issued daily at the Central Telegraph Office, which are much appreciated by the public.

5. No special line of investigation is being undertaken.

6. The grant for Meteorological work is merged in the whole grant for the maintenance of the Observatory.

XXV.—Tasmania.

Observatory, Hobart.—Mr. H. C. Kingsmill, Meteorologist.

1. Meteorological observations in Tasmania were begun by Sir John Franklin in 1840. Being Governor of the island, then called Van Diemen's Land, he sent home for instruments, and when Captain Ross arrived at Hobart in August 1840 in command of the *Erebus*, an observatory was built near Government House, and 3 magnetometers, transit, clocks, and other instruments set up. Lieut. Kay was put in charge of the Royal Observatory, which was called "Rossbank." Lat. 42° 52′ 27″·4 S., long. 147° 27′ 30″ E. Mean magnetic dip 70° 40′ S. Variation 10° 24′ 24″ E. Here Lieut. Kay took hourly observations for eight years, Sir John himself helping in the magnetic observations.

Mr. Francis Abbott, who had a private observatory in Murray Street, carried on observations tri-daily from 1841 to 1880. Being a member of the Royal Society of Tasmania, he supplied them with monthly meteorological reports, which are published in their yearly reports. Observations were taken of barometer, temperature, humidity, clouds, and rain. In 1858 ozone was added.

Observations were also started of rainfall, etc., by the Marine Board at the lighthouses under their care, and by gentlemen in different parts of the island.

Mr. Francis Abbott was obliged to relinquish his work in March 1880, and in 1881 observations were taken only at New Norfolk by Mr. W. E. Shoobridge. In 1882 Capt. Shortt was asked by the Royal Society to undertake the work. In March 1883 a deputation from the Royal Society waited on the Premier, and asked him to establish a Government Observatory. This was done, and the present Observatory in the Barracks was started under Capt. Shortt in 1883. Capt. Shortt remained in charge till his death in 1892, when Mr. H. C. Kingsmill, the present Meteorologist, was appointed.

2. The present state of the organisation is as follows:—First order stations, 2; second order stations, 6; climatological stations, 2; rainfall stations, 65.

3. No weather forecasting is undertaken by this Office, as we do not get sufficient information by telegram. Daily forecasts are, however, issued by Mr. Wragge, Government Meteorologist of Brisbane, and these are published in the daily press.

4. The following is a list of completed investigations:—(1) Mean temperature of Hobart, from hourly observations for 8 years; (2) mean quarterly temperature, mean annual variation, and mean diurnal variation from hourly observations for 8 years; (3) mean rainfall for 12 years; (4) results of 35 years' observations at Hobart Town.

5. Investigations now in progress are:—(1) The relation of the distribution of icebergs to the rainfall; (2) simultaneous observations at high and low level stations—Hobart and Mt. Wellington summit.

6. The Government vote is £325 for the Meteorological Department, distributed as follows:—Meteorologist, £125; observers, £60; contingencies, £115; Mt. Wellington, £25.

XXVI.—Victoria.

Observatory, Melbourne.—Mr. P. Baracchi, Government Astronomer.

1. There are no records of any systematic meteorological observations made in this colony previously to 1855, although we possess some broken series made with doubtful instruments, as well as regular tables of barometric readings taken at lighthouses and light-ships with common marine instruments, but not sufficiently reliable for any proper use of them to be made.

Systematic and reliable observations in Melbourne, and at two or three other places, were commenced in 1855 under the control of the Crown Lands Department, and under the special care of Mr. Brough Smyth; these were continued till March 1, 1859, and on that date Prof. Neumayer took complete charge of the work at his observatory on Flagstaff Hill, Melbourne, which he established by private resources one year before. The systematic meteorological work of the Flagstaff Observatory, under Prof. Neumayer, commenced on March 1, 1858, and continued until his departure for Europe in 1863. I need not refer here to his results, which are fully set out in his published volumes.

In 1863 the Meteorological and Magnetic Observatory of Prof. Neumayer was amalgamated with the Astronomical Observatory under the direction of Mr. R. L. J. Ellery, then Government Astronomer to the Colony of Victoria, who steadily expanded and controlled it till his retirement in June 1895, when I succeeded him, remaining in charge of the Department to the present date.

Up to 1871 there were really only about 16 reliable stations in the colony furnishing regular results. After that year the Meteorological Service commenced to extend vigorously. In 1872 the publication of meteorological and magnetic results commenced, consisting of monthly pamphlets, to which I would refer you if you wish to ascertain the progressive extension of the service from year to year. In 1876 there were already 13 barometric stations reporting daily to the Observatory by telegraph. In that year the publication of weather bulletins was initiated. These gave the existing weather conditions, especially along the coast; the inter-colonial telegraphic exchange of daily weather reports commenced in this year (1876).

In 1879 there were 89 stations, 7 of which sent complete monthly returns of pressure, temperature, rainfall, wind and weather, 17 sent daily telegraphic reports, and 65 sent the rainfall only.

The first weather charts were prepared and issued with forecasts in December 1881.

2. The Meteorological System comprises in all 573 stations, of which 465 are supplied with observatory instruments. There are 20 barometric stations, 40 temperature stations, and 513 rainfall stations.

3. The present percentage of success is 85. This figure has been arrived at by a comparison of the last 1000 daily 6 p.m. forecasts, with actual weather occurring during the 24 hours following.

4. Average monthly and yearly distribution of rainfall over the various districts of the colony, based on all obtainable records.

5. Cloud observations by a number of observers without special instruments, and determination of absolute height and velocity of clouds by the photographic method. This is in connection with the scheme of the International Meteorological Committee. The observations of form and apparent velocity were completed in 1897. The photographic operations will be continued to the end of the current year.

6. As the Meteorological Department is amalgamated with, and forms a part of, the Melbourne Observatory, which is chiefly an astronomical institution, it is difficult to give a correct estimate of the actual cost of the Meteorological Service. We may arrive at it in this way:—

To Telegraph and Postal Department for Weather Telegrams and Postage	£1,600
Bonus to Observers, and Purchase of Instruments	200
Salaries—a telegraph clerk, other clerks and officers who only devote a portion of their time to meteorological work, messengers, etc. .	500
	£2,300

XXVII.—Western Australia.

Observatory, Perth.—Mr. W. E. Cooke, Government Astronomer.

1. A distinct branch of the Surveyor-General's Department for Meteorology was created in January 1876 under the superintendence of Sir Malcolm Fraser. Previous to this, readings of an aneroid and a thermometer had been taken, but Sir Malcolm obtained a mercurial barometer and Kew-tested thermometers, including maximum and minimum, and mounted these latter on a Greenwich stand. Next year ten rainfall stations were established, and in 1880 mercurial barometers and self-registering thermometers were sent to six out-stations. As time went on, other stations were formed owing to the energy of Mr. M. A. C. Fraser, who was the Meteorological Reporter, and had practically the charge of the work from the commencement, until in 1896 there were 18 second class and 135 rainfall stations.

In February 1896 the Government decided to build an Astronomical Observatory, and I was appointed Astronomer and at once took charge of the Meteorological Department. I thoroughly reorganised the out-station work, which, for lack of periodical inspection, had been rather neglected, saw that each station had a Stevenson screen properly mounted, substituted new for worn-out or defective instruments, and personally instructed each observer in the methods of reading, etc.

2. The Observatory is not yet finished, but a set of thermometers was exposed in a Stevenson screen on an open expanse of lawn in January 1897, and systematic readings have been taken since then. Two solar radiation thermometers, a pluviograph, an atmidometer, a sunshine recorder, and a rain-gauge are mounted near by, and it is proposed to keep this lawn free for all time (at all events during the present Astronomer's directorship) from tall trees and buildings, so that from the very commencement of taking observations the records may be comparable year by year. In another part of the grounds is a second screen, wherein a good dry-bulb and an electric resistance thermometer are mounted, also a Richard's thermograph. Close to this screen four electric resistance thermometers are sunk in the ground to depths of 8 ft., 5 ft., 3ft., and 9 inches respectively, and a sixth, with the platinum coil blackened and enclosed in vacuo, is mounted on an adjacent post to measure solar radiation. These were manufactured by the Cambridge Scientific Instrument Company, and are known as Griffiths and Callendar's pattern. There is also a standard barometer, a Redier's barograph, and an anemograph.

There are 31 stations of the second order, equipped with mercurial barometer, dry and wet bulbs, maximum and minimum thermometers, 8-inch rain-gauge, wind-vane, and Stevenson screen. There are 218 rain-gauge stations. At the second order stations observations are taken at 9 a.m. and 3 p.m., and the monthly sheets are checked and analysed for possible errors at the Observatory as soon as received. In addition, readings are taken at 8 a.m. and telegraphed to the Central Office for inclusion in the daily weather reports. The direction and force of the wind, amount of the rainfall for previous 24 hours, and state of the weather and sea are also wired daily from almost every telegraph office in the colony.

With the exception of Hall's Creek, Hamelin Pool, and Eyre (each of which is difficult of access), an endeavour will be made for an inspecting officer to personally visit each station at least once a year.

3. Weather forecasts were first issued at the commencement of the present year. They are based upon observations taken at 8 a.m. in this colony and 9 a.m. (local time) in the other colonies, and are issued at about noon. For the first six months the results were :—

		Percentages
Quite correct	140	93
Partially correct	9	6
Totally wrong	1	1
Forecasts issued	150	

Since June 17 a supplementary weather report is received from 8 selected stations, and a second forecast telephoned to the Press at 8 p.m. for insertion in the morrow's papers. The noon forecast is therefore now made to cover only up to the following morning, and the 8 p.m. one covers the whole of the following day. Up to date (August 1) one of these latter has been partially wrong and one wholly so. All the rest have been quite correct.

4 and 5. The work hitherto has consisted of organisation, keeping the reports corrected and checked up to date, and entering up back records in ledgers. There has been no chance of original investigation, but I am taking photographs of clouds with a view of utilising these more than is at present done in forecasting.

6. The total expenditure on the Observatory for last year was £3068 : 8s. Most of this was spent for meteorological purposes, but when the astronomical instruments are in working order, and back meteorological work brought up to date, at least half the amount voted will be spent in the service of astronomy.

XXVIII.—Cape Colony.

Meteorological Commission, Cape Town.—Mr. C. Stewart, Secretary.

1. The first Meteorological Commission was appointed by Government Notice No. 363, dated October 26, 1860, and stated that: "His Excellency the Governor, being desirous of establishing simultaneous and systematic meteorological observations at eligible positions in the Colony, in order to obtain data on which to found measures of practical utility, has been pleased to appoint a Committee, consisting of the undermentioned gentlemen, to undertake the charge and distribution, on loan, of the instruments purchased by Government for the purpose. . . . Parties wishing to aid the Government, by undertaking to make observations, are requested to send in their names, addresses, and such information as to the locality of dwelling and southern aspect of dwelling as will guide the Committee in selecting the individuals between whom the limited number of sets of instruments should be distributed," etc.

The members of the first Meteorological Commission were:—The Hon. Richard Southey, Acting Colonial Secretary, Chairman; Sir Thomas Maclear, F.R.S., H.M.'s Astronomer; Charles Bell, Surveyor-General; John Scott Tucker, Colonial Engineer; and Rev. J. C. Adamson, D.D.

The first Report was published on July 7, 1862, and contained the following Introductory Remarks:—"Nearly half a century ago, the Colonial Government showed some interest in the Meteorology of this Colony. Instructions were given to their officers in the country districts to make observations and to transmit their registers to the metropolis. Some of their returns were occasionally published. But want of attention to the individual character of the instruments and of their localities, and the consequent impossibility of applying the requisite corrections, along with the desultory character of the observations, combined to render these returns of little value to science. In 1831, at the establishment of the South African Institution, the subject was resumed more systematically. Matters of some permanent interest are to be found in Reports issued by a committee of that body from 1831 to 1837. The returns of observations which were then procured by them partook of the character already noticed, so that conclusions drawn from them would not correspond to the

present state or present aims of the science. Their Reports, however, contain notices which have led to important consequences; and they indicate, in certain instances, modes of attaining results which it may be useful not to lose sight of."

The Commission was re-appointed, with some changes, in 1865.

The results of the observations were published in the Blue Book for the Colony up to 1868.

In 1875 the Commission was re-organised, and the Reports published separately, and presented yearly to Parliament ever since.

The meteorological observations are mostly taken by voluntary observers, who are presented with the instruments under their charge after taking a series of five years' observations.

Rainfall observations form part of the duties of various Government officials, *e.g.* gaolers, officers of the Forest and Agriculture Departments, etc.

The Chairman appointed in 1875 was the Hon. C. Abercrombie Smith, who continues to fill this post at the present time.

The names of the various Secretaries to the Commission are:—1862, W. L. Blore; 1870, C. B. Blore; 1874, A. Viner Solomon; 1876, W. Greathead; 1878, J. W. Bailey; 1879, W. Ellerton Fry; 1890, Staff-Commander D. J. May, R.N.; 1893, Roland Pillans; 1897, Charles Stewart, M.A.

2. The numbers of the various orders of stations in Cape Colony, including British Bechuanaland, are as follows:—second order stations, 54; third order stations, 19; rainfall stations, 378.

Although the second order stations are fairly numerous, they are very unequally distributed; but active steps are being taken at the present time to remedy this defect, especially in the western and central parts of the Colony, where it is very difficult to find suitable observers with sufficient intelligence to undertake the work.

Although we have no first order stations, I hope to secure the observations made at the De Beers Company's station at Kenilworth near Kimberley, where there is the only first order station in South Africa, under the care of Mr. J. R. Sutton, B.A.

In addition to stations actually within the Cape Colony, we receive returns from 8 stations in Basutoland, 11 in Orange Free State, Durban in Natal, 3 in Johannesburg, S.A.R., 1 in Swaziland, 2 in Rhodesia, and 5 in Damaraland.

3. No weather forecasting has been undertaken, partly for the reasons above stated, and also owing to the heights of our stations being only approximately known,—very few having been ascertained by direct measurement.

4. The only investigation that has been completed is in connection with the rainfall; the maps, etc., being first prepared by Mr. J. G. Gamble, and published in the Commission's Report for 1886.

The latest investigation of the same phenomenon was carried out by Dr. Buchan, Secretary of the Scottish Meteorological Society, and published last year.

5. No other investigations have been carried out, owing to the whole management devolving on the Secretary, whose time is fully occupied in the distribution of instruments, checking and publishing the returns, inspecting stations, etc.; and, as will be seen from the number of stations, no time can be given over to any other work.

I intend entering upon an investigation of the winds, at three stations representative of the west, east, and centre of the Colony, whenever the opportunity occurs.

6. The amount of grant from Government is £600 per annum, to pay for office and store rent, salaries, printing of stationery, etc., cost of inspections, cost of instruments (except rain-gauges, which are paid for by the Public Works Department), etc.

XXIX.—Mauritius.

Royal Alfred Observatory, Pamplemousses.—Mr. T. F. Claxton, Director.

1. Meteorology seems to have engaged the attention of Mauritians from very early times. As far back as the year 1695, mention is made of an "ouragan" or hurricane (*Almanach de l'île Maurice*, 1837), but no systematic observations appear to have been made till the time of M. Lislet Geoffrey, who from 1786 to 1792 conducted an important series of magnetical and meteorological observations, a résumé of which is given by M. Louis de Freycinet in his *Voyage autour du Monde*, Paris, 1827.

The first attempt at establishing a Government Observatory, however, was made in 1830 by Colonel Lloyd, then Surveyor-General. He erected a building in Port Louis, at the public expense, and fitted it up with a transit and magnetical and meteorological instruments. Observations were commenced on January 1, 1832, and were continued, with occasional breaks, until he went to England on leave of absence in October 1837, and ceased altogether on his departure from the Colony in 1849.

On August 1, 1851, the Mauritius Meteorological Society was founded, by the united efforts of Mr. C. J. Bayley, Lieut.-Col. Robe, C.B., Lieut. Fyers, Mr. C. Meldrum, and others, for the express purpose of establishing a permanent Magnetical and Meteorological Central Observatory, with branches in different parts of the island and its dependencies, and for collecting information from log-books with a view to the further development of the Law of Storms, etc. Its first President was Mr. C. J. Bayley, with Messrs. Meldrum and Bousquet as Joint Secretaries.

The Colonial Government voted an annual grant of £200 to the Society, out of which the Government Meteorological Observer was to receive £100. The Observatory building was handed over as a place of observation, but the Society was soon called upon to pay rent to Government at the rate of £60 per annum: it was further necessary to provide the Government Observer with an assistant at a yearly stipend of £36, which left the Society a balance of £4 per annum for carrying out its objects.

In the year 1852 Mr. H. Bousquet was appointed to fill the post of Government Observer. He made certain meteorological observations, which apparently were never published, and devoted his spare time to the study of the Law of Storms. Extracts were made and collated from all available log-books, and by this means a daily weather journal of the Indian Ocean kept and the tracks of cyclones laid down, which practice is continued to the present time.

In the month of November 1852 observations were commenced by Capt. (then Lieut.) Fyers, R.E., at the Royal Engineers Establishment, near the Government Observatory; and in January 1855 Lieut. Fyers, who had recently been elected Secretary of the Meteorological Society, was appointed Government Observer vice Mr. Bousquet, resigned. In August 1858 Capt. Stokes, R.E., succeeded Capt. Fyers as Secretary of the Meteorological Society and Government Observer.

During this time the meteorological instruments received by the Society in 1853 were lying idle, and it was not until the beginning of the year 1859 that they were installed in the old Government Observatory and regular observations started. In September of the same year Dr. (then Mr.) C. Meldrum was elected Secretary of the Meteorological Society, and in March 1862 appointed Government Observer.

Though up to now the observations had been made in Port Louis, which is encircled from west-south-west through south to south-east and east by a range

of mountains, the want of an Observatory in a more suitable locality had never been lost sight of. The subject was brought to the notice of the Government in 1853 by Dr. Thom, the President of the Society, and later by some of his successors. At length, in April 1860, Col. Sir Henry Johnson, President at the time, again brought it forward, recommending that the Observatory be sold and the proceeds devoted to the purchase of a more suitable building. Some time afterwards the Governor, Sir William Stevenson, replied that the matter was under consideration, and requested the Society to look out for a site. A Committee was appointed for this purpose, and finally decided on the present site at Pamplemousses, seven miles to the north-north-east of Port Louis, but their report was not ready before His Excellency's death occurred.

Much anxiety was felt as to what attitude the new Governor might assume; but fortunately Sir Henry Barkly succeeded, and at once took the matter in hand. The old Observatory was sold, and £5200 voted for a new building and instruments; also the Government Observer was authorised to proceed to England to procure the latter and obtain plans for a new Observatory. In the meantime the daily meteorological observations were taken in a small building in Little Mountain Street, Port Louis, under the direction of the Rev. G. M'Irvine, M.A.

In October 1869 Dr. Meldrum returned, and a set of Kew-pattern self-recording magnetical instruments and a barograph arrived in July of the following year. On Monday, May 30, 1870, the foundation stone of the new observatory was laid by His Royal Highness the Duke of Edinburgh, in the presence of His Excellency Sir Henry Barkly, the President and Council of the Meteorological Society, and a numerous company of the surrounding inhabitants.

In order that the Government Observer might watch and generally supervise the building of the new Observatory, the meteorological instruments were removed, at the end of the year 1870, from Little Mountain Street to Maison Baulle, a commodious house two miles to the south-east of the new site, and it was not until the beginning of the year 1875 that they were installed in the new Observatory and the regular observations initiated under the direction of Dr. C. Meldrum, F.R.S. Dr. Meldrum's title of "Meteorological Observer" was altered to "Director of the Royal Alfred Observatory" in 1875, which post he filled with honour until the year 1896, and was succeeded by Mr. T. F. Claxton, F.R.A.S. In the meantime the self-recording magnetographs and barograph had been set up in the underground chamber prepared for their reception; a photoheliograph, an equatorial, and a transit instrument mounted, and also a self-recording Beckley anemometer. The instruments have been maintained in good working order up to the present time.

A Beckley thermograph was received in the year 1875, but continuous photographic records of the temperature of the air and evaporation have only been obtained since January 1891.

In the year 1884 two actinometers were ordered at the suggestion of Sir John Pope Hennessy: they arrived in the following year, and one was mounted at the Observatory. It was intended that observations should be made both at the Observatory and at Curepipe, a town near the centre of the island, 1850 feet above sea-level, but it was found impossible to carry out the original project. However, observations have been made as frequently as possible at the Observatory.

Continuous automatic registers of the amount of sunshine have been obtained without interruption since the arrival of an improved Campbell Sunshine Recorder in 1886.

2. It will be seen that the Observatory owes its existence to the Mauritius Meteorological Society. Commencing in 1851 by taking desultory meteorological observations and making extracts from log-books of ships for determining the

tracks of cyclones, the meteorological organisation of Mauritius now consists of a Central Observatory at Pamplemousses, receiving rainfall returns from 70 stations in different parts of the island, from 6 of which observations of temperature are also received. Bi-daily observations of atmospheric pressure, temperature of the air, wind, and weather have been received from Port Mathurin (Rodrigues) since 1876, Mahé (Seychelles) since 1881, Six Islands (Chagos Archipelago) since December 1897, and St. Brandon (Cargados Archipelago) since June 1898. The observations are reduced at the Central Observatory, and the results published in the annual volume.

3. Storm warnings are issued during the hurricane season, and notice given of the existence of Cape gales during the winter months; but no daily forecasts are attempted, as, unfortunately, there is no telegraphic communication with outlying stations.

It is seldom that a cyclone approaches to within 300 or 400 miles of Mauritius without its existence being known for at least 48 hours beforehand: the percentage of failures in storm warnings is therefore small.

4. In the course of his career Dr. Meldrum made certain investigations into "The Law of Storms"; "The Oscillations of the Barometer at Mauritius in connection with Cape Gales"; "Sunspots and Cyclones"; "Sunspots and Rainfall"; and "On the Relations of Weather to Mortality in Mauritius, and the Climatic Effects of Forests."

Daily weather charts of the South Indian Ocean for the three months January, February, and March 1861 were prepared by him and published under the auspices of the Mauritius Meteorological Society. The tracks of all known cyclones which occurred from 1848-85 were published by the Meteorological Council in 1891, and those for 1886-96 were forwarded to the Hydrographer to the Admiralty in the year 1897.

The practice of keeping a daily weather journal of the South Indian Ocean is still maintained, synoptic charts prepared for those days on which bad weather has been experienced, and the tracks of cyclones laid down.

5. An investigation into the cause of diurnal variation of rainfall at Mauritius is at present engaging the attention of the Director.

A résumé of all the observations of upper clouds for the past 20 years is nearly ready, as is also a résumé of the actinometric observations from 1886-97.

6. The maintenance of the Observatory is undertaken entirely by Government, and necessitates an annual expenditure of Rs.20,000, or about £1300.

XXX.—Natal.

Observatory, Durban.—Mr. E. Nevill, Government Astronomer.

1. The Meteorological Organisation in Natal is still primitive.

For about ten years prior to the founding of the Astronomical Observatory in 1882, a yearly grant was made to the Botanic Societies of Durban and Maritzburg on the condition that they made regular meteorological observations twice daily. Observations were made, though somewhat irregularly; but the records appear to have disappeared, and cannot be traced. [For Dr. Mann's observations see note, p. 83.]

From 1883 until 1891 the only observations made were those at the Astronomical Observatory at Durban, no attempt being made to continue those at the Botanic Gardens, the results published by the Botanic Society at Durban being obtained from the Observatory.

In 1891 a small vote of £50 was made to furnish 5 stations in the coast districts of Natal with rain-gauges and maximum and minimum registering

thermometers. The observations were taken by police or gaol officials, all untrained, and great difficulty was experienced in obtaining either regular or certain observations. In the year 1893, 8 more stations were similarly equipped, and in 1895, 8 more stations, making 21 in all. Regular returns, however, are only received from about two-thirds of these stations.

2. Details as to the number and position of the subsidiary stations, and records of the observations made, will be found in the Annual Reports of the Natal Observatory.

3. With respect to weather forecasting or other meteorological investigations, some material is being accumulated, but it is doubtful if anything can be done unless our stations are properly equipped with something more than a rain-gauge and thermometer.

6. No special vote is made for meteorological work, the expense coming out of the ordinary vote for the Astronomical Observatory, and a considerable part of the expense of maintaining this has for years fallen on the Astronomer. The actual cost of the meteorological work done at the Observatory, including maintenance of instruments at the subsidiary stations, is about £200 a year.

XXXI.—Canada.

Meteorological Service, Toronto.—Mr. R. F. Stupart, Director.

1. Meteorological observations were commenced at the Toronto Magnetic Observatory in 1841, and have been carried on ever since without a break.

Prior to the autumn of 1869 there were but few meteorological observers in the Dominion of Canada, and there was an absence of that unity of action by which the scanty materials that did exist could be combined so as to yield satisfactory results. Being dissatisfied with a state of affairs so discreditable to the meteorology of Canada, and resolving that it should continue no longer, Prof. G. T. Kingston, the Director of the Toronto Magnetic Observatory, addressed himself by letter and in person to those actually engaged in meteorological observations, and also to others in various parts of the country, requesting their co-operation, and offering to make arrangements whereby all observations might be carried on in accordance with instructions issued by himself, and might be reported to him at Toronto regularly from month to month. The result was a steady increase in the number of observers, and in the exactness and regularity of the observations.

From October 1869 to the spring of 1871 the meteorological work of Canada was carried on by an organisation that was strictly voluntary. No emoluments whatever were attached to the services of the observers, and the instruments were either private property, or were provided on loan from the Toronto Observatory, from which establishment forms for registration were also furnished. The work of organising new stations and of compiling returns was performed gratuitously by Prof. Kingston and his assistants.

In the spring of 1871 the Dominion Government recognised the values of these labours by a grant of $5000 for the promotion of meteorological research, and with a special view of preparing the way for establishing a system of storm-signals. Early in 1872 arrangements were made for the telegraphing of tri-daily reports from several stations in the region of the Great Lakes to Toronto, and these were forwarded to the Chief Signal Officer at Washington, D.C., who in return supplied Prof. Kingston with reports from 15 stations in the United States. In July 1872 the annual grant was increased to $10,000, and a steady increase was made during the next four years in the number of reporting stations, and the equipment of storm-signal masts.

Up to the autumn of 1876, the Canadian Service relied on the courtesy of

the United States Service for storm warnings, which were forwarded with regularity from Washington whenever any serious disturbance was indicated by the weather chart. In September of that year, however, warnings were issued to Canadian ports without waiting for notification from the United States, and in October regular daily forecasts were issued at 10 a.m. for the next 24 hours.

2. There are now in the Dominion 364 stations at which observations are taken with instruments supplied by the Government, and which report to the Central Office, Toronto. They are divided as follows:—9 chief stations, 60 first order, 206 second order, and 89 third order: or in the International Classification:—4 first order, 65 second order, 206 third order, and 89 rain-fall stations.

3. Thirty-one stations report by telegraph twice daily, and 2 stations—St. John's, Newfoundland, and Bermuda—once daily (these are paid for by the Dominion Government). The telegraph reports comprise the barometer readings reduced to sea-level, the readings of the dry and wet thermometers, the direction and velocity of the wind and state of the weather, the precipitation (if any), and with the morning report the minimum temperature of the preceding 12 hours, and with the evening reports the maximum of the preceding 12 hours. Almost invariably all reports from stations between Lake Superior and Cape Breton are received in the Central Office by 8.30 a.m. and p.m., and are then forwarded without delay to the United States Weather Bureau at Washington *via* Buffalo, N.Y., from which place the reports of some 60 United States stations are in return sent to Toronto, together with the Canadian reports from Manitoba westward to British Columbia, which are turned over to the United States Bureau at St. Paul, Minnesota. All reports are usually received shortly after 9.30 a.m., and the working chart is ready for the forecasting official by 9.45 a.m., and by 10 o'clock a.m. the isobars have been drawn and some of the forecasts telegraphed to their destination. The bulletin issued at night comprises a short synopsis of the weather during the past day, and generally a description of the existing meteorological conditions, then a list of the highest and lowest temperatures reported from about a dozen stations, followed by the forecasts for the various districts lying between Manitoba and the Maritime Provinces. These forecasts are for the 24 hours beginning the following 8 a.m., unless it be expressly stated that they cover a longer period. That same evening the Telegraph Company sends the bulletin to all points where are published morning newspapers, in which it is printed generally at the head of the column of local news; and then in the morning, on the opening of the various telegraph offices throughout the Dominion, the first message which goes over the wires is the daily forecast, which is posted up in a conspicuous place in every telegraph office. Up to the summer of 1894, the forecast based on the 8 p.m. chart was practically the only one issued, but since that time a second forecast covering the current and following day has been issued at 10 a.m.; this is sent to nearly all ports both on the Great Lakes and on the Seaboard, and recently arrangements have been made whereby it appears in most of the afternoon newspapers published in the Dominion.

There are in the Dominion 67 stations at which cautionary and storm signals are displayed: 33 on the Lakes, and 34 in the Maritime Provinces. The signals used are drums and cones; the cone alone being hoisted when but a moderate gale is expected, and both drum and cone together when it is thought that the storm will be heavy. The apex of the cone downwards indicates Southerly and Easterly directions, and upwards Northerly and Westerly.

As a means of disseminating more generally the forecasts among the farming community during the summer season, white discs indicating "Fine," "Showers," or "Rain" are placed each morning on the baggage vans of outgoing trains.

Until within a few months past, forecasts were not issued for portions of

the Dominion lying west of Manitoba, but very recently arrangements have been made whereby telegraphic reports from stations near the Pacific Coast and in the North-West Territories are forwarded twice daily to Victoria, British Columbia, at which place the agent of the Meteorological Service is local forecast official, and now issues regular daily forecasts based on a weather chart as nearly complete as will be possible until telegraphic communication be established with more northern regions.

The percentage of verification of storm warnings for the year 1897 was 84·9, and the percentage of verification of the daily 36-hour forecasts was 81·4.

6. In 1880 the grant from the Government was $37,000; in 1885, $50,300; in 1890, $55,000; in 1892, $62,900; and in 1898 (current year), $63,000 (£12,936).

In 1880 Mr. Charles Carpmael, M.A., Fellow of St. John's College, Cambridge, succeeded Prof. Kingston as Director, and in 1894, on his death, Mr. R. F. Stupart, who for some years had been chief forecast official, was appointed Director of the Service.

XXXII.—Mexico.

Central Meteorological and Magnetical Observatory, Mexico.—
Sr. M. Bárcena, Director [deceased April 1899].

1. Meteorological observations seem to have been carried on in Mexico more or less continuously from about 1768. The first observer whose name has come down to us was the priest José Antonio Alzàte, who was the first to determine the height of the city of Mexico. From 1824 onwards, with divers interruptions, observations were carried on in the city of Mexico till March 6, 1877, when the Central Meteorological Observatory was established by the President, General Porferio Diaz, at the suggestion of General Vicente Reva Palacio, Secretary of Public Works. Other observations were also made in different parts of the country, commencing with 1855 and continuing till 1877, when the several stations which then existed were absorbed by the new organisation. The first chief of the new organisation was the Director Mariano Bárcena, the Vice-Director being Miguel Perez, the second observer being José Zendejas, who is now the Sub-Director.

2. The existing organisation is:—The Central Meteorological Observatory of the first order. The stations of the second order, which possess a more or less complete set of instruments, and take at least three observation daily, are 28 in number. The stations of the third order may be taken as those sending telegraphic reports, which only send the general conditions of weather; they have no instruments, or at most only a thermometer. At present, agents or other persons take observations with the instruments belonging to the harbour-masters at a few of the ports.

Most of the persons who take observations at the above-mentioned places do so voluntarily. The only official stations belonging to the Federal Government are the Observatories at Mexico and Mazatlan. Those belonging to the States are 16 in number. The gentlemen who take these observations in the capitals of the various States are professors at the respective colleges, and the remuneration for the observations is small.

3. Weather forecasts are not issued owing to the small number of stations, while the extent of the Republic is very great, and of various geographical aspects.

6. The annual expenses of the Meteorological Service may be stated as follows:—

Central Observatory	$12,000
Mazatlan	5,000
The Central Observatory cannot state the amount spent by the States precisely, but it may be estimated at	20,000
Instruments and other expenses	3,000
Total (say £8600)	$40,000

At Chihuahua, the capital of the province of the same name, an observatory is about to be established. The instruments have already been provided at a cost of over 2000 pesos (say £400).

XXXIII.—United States.

Weather Bureau, Washington.—Prof. Willis L. Moore, Chief.

1. The present U.S. Weather Bureau began its official existence by the transfer to the Department of Agriculture, July 1, 1891, of the meteorological work that had been organised in the War Department by the Chief Signal Officer of the Army, in accordance with an Act of Congress dated February 4, 1870. This action on the part of the Congress of the United States was the final step in a series of movements that began many years ago.

(*a*) In 1807 Col. Jared Mansfield, the first Surveyor-General, organised a system of daily weather observations; and in 1817 his successor, Josiah Meigs, as Commissioner of the General Land Office, extended this system to twenty land offices scattered throughout the Federal territory from Michigan to Louisiana and from Ohio to Missouri. Eventually these stations became obsolete as a land office system.

(*b*) Organised meteorological observations for climatological purposes were instituted by Surgeon-General Joseph Lovell in 1819, as a duty of the whole medical staff of the Army. It is likely that some six years previous to that date similar duties had been required of the hospital surgeons by Dr. James Tilton, who was appointed physician and Surgeon-General in 1812. These Army post stations are still maintained, and the reports are utilised by the Weather Bureau.

(*c*) In 1825 the Regents of the University of the State of New York established a system of stations recording at least temperature and rainfall, some of which still continue.

(*d*) In 1837 the Legislature of the State of Pennsylvania appropriated funds to defray the expense of stations in that State, and solicited voluntary records from other States. This work was initiated and fostered by the so-called Joint Committee of the American Philosophical Society and the Franklin Institute, of which James P. Espy was the leading spirit. The main idea of this system was to study the details of storms.

(*e*) In 1841 Henry L. Ellsworth, Commissioner of Patents, organised a system of meteorological reports for the study of climate in connection with the statistics of crops, and began publishing climatological data in his annual reports.

(*f*) In 1849 the Patent Office, with its agricultural work, became a part of the Department of the Interior, and largely increased its climatological work.

(*g*) In 1847 Prof. Joseph Henry, on behalf of the Smithsonian Institution, began the organisation of a system of stations and reports covering the whole subject of American climatology and meteorology: its special object was "the solving the problem of American storms." The Smithsonian system soon extended over the whole of the habitable part of North America, and continued in active operation until 1873, when Prof. Henry deposited his records with

the Signal Office, and requested his observers to co-operate with that Bureau. From 1849 onwards a selection from the Smithsonian records and an excellent series of papers by Prof. Henry were published in the climatological portions of the successive annual reports of the Commissioner of Patents and his successor the Commissioner of Agriculture, Hon. Isaac Newton. The co-operation between Prof. Henry and the Commissioner of Agriculture led Mr. Newton, in his first and second annual reports (1862), to recommend that the Government establish a system of daily telegraphic weather reports, in continuation of that which the Smithsonian Institution had maintained for many years.

(*h*) About 1863 the Chief of Engineers of the U.S. Army organised a system of stations covering the region of the Great Lakes. The observations were published in the annual reports, and, even as early as 1864, it was urged that this system could be developed into a system for storm predictions.

(*i*) In 1869 the Cincinnati Observatory was authorised by the Chamber of Commerce in that city to organise a system of weather reports and predictions for the use of the public. This movement represented the high state of intelligence among the leading merchants of that city. After the daily weather bulletin had begun to appear regularly, these gentlemen, through their representatives on the National Board of Trade, represented the importance of the subject so strongly to that body, that it gave its hearty endorsement as to the necessity of a national Weather Bureau proposed by Gen. H. E. Paine of Milwaukee, Wis., and his friend the Hon. I. A. Lapham of that city. Fortified by memorials from all the important Boards of Trade and Chambers of Commerce, Mr. Paine soon afterwards introduced a joint resolution before the Congress of the United States, which on February 9, 1870, by the signature of the President, became an Act, authorising "the Secretary of War to take meteorological observations at the military stations in the interior of the continent, and at other points in the states and territories of the United States, and to give notice on the Northern Lakes and Sea-coast, by magnetic telegraph and marine signals, of the approach and force of storms."

Mr. Paine had originally contemplated a semi-scientific organisation, but at the discussion of his Bill before a Committee of Congress, the Chief Signal Officer of the Army, Gen. A. J. Myer, had appeared, by permission of the Secretary of War, and had offered his services in the execution of this great work. This accounts for the fact that storm and weather predictions were now committed to the care of a branch of the Government service, different from any of those that had hitherto distinguished themselves for work in meteorology. In addition to the prediction of storms, the Appropriation Bill of June 1871 furthermore provided for reports relative to the stages of water in the rivers and the announcement of floods. In fact, the Signal Service had, during the few months preceding that date, demonstrated its ability to do far more than the mere prediction of storms. The Appropriation Bill of June 1872 provided for predictions for the benefit of agriculture as well as commerce, and ever since that time the duties of the Weather Bureau—whether under the Secretary of War or the Secretary of Agriculture—have officially included nearly every form of meteorological work that could affect, or benefit, any material interest of the citizens of the United States, whether at home or abroad.

To the preceding lines we may add the following details:—

At first, the Weather Bureau was popularly entitled "The Weather Bureau of the Army Signal Office," or briefly, "The Signal Service"; but its official designation as a part of the office was "Division of Telegrams and Reports for the benefit of Commerce and Agriculture," as distinguished from the "Division of Military Signalling and Telegraphy." A school of instruction was established at Fort Whipple—now Fort Myer—near Washington. The personnel of the service consisted of Col. (afterwards Brig.-Gen.) A. J. Myer, who had been

commissioned as Chief Signal Officer of the Army in 1860, and, far below him, the privates and sergeants subsequently known as observer-sergeants in the Signal Corps. A large majority of these had been specially enlisted for meteorological work, but were subject to any other military duty that might be imposed upon them. Besides these, there were a number of commissioned officers of the Army, who were temporarily assigned from their respective regiments to receive instruction in signalling, and to special duties as assistants under the Chief, but none of these were considered to belong to the permanent Signal Corps.

The course of instruction was now enlarged to include both military signalling and all the duties of a meteorological observer. As every man became a fairly good telegrapher, and as the Service has occasion to build and operate telegraph lines, this combination of meteorology and telegraphy is often of great advantage.

In addition to the corps of enlisted men and commissioned officers, a few civilian experts were also attached to the Signal Service. Beginning with the Chief Clerk and Electrician, and Prof. I. A. Lapham (temporarily) as Meteorologist, in November 1870, the number of these civilians slowly increased up to the date of the transfer in 1891. During that interval of twenty years, provision had also been made by Congress for the gradual growth of a Signal Corps of commissioned officers to be selected from among the most worthy observer-sergeants.

During these years the Chiefs of the Signal Corps were as follows:—

Gen. A. J. Myer, the founder, in 1858, of the Signal Corps as a military service, and the organiser, in 1870, of its meteorological work; appointed Chief Signal Officer in 1860. Died August 24, 1880.

Adjt.-Gen. R. C. Drum, temporarily acting as Chief Signal Officer during the remainder of 1880.

Brig.-Gen. W. B. Hazen; appointed Chief Signal Officer in December, 1880, and died January 16, 1887.

Brig.-Gen. A. W. Greely; temporarily appointed Acting-Chief Signal Officer during Gen. Hazen's illness, in December 1886; eventually appointed Chief Signal Officer of the Army, March 1887, and still holds this position.

During the fourth year of Gen. Greely's administration, by virtue of the Act of Congress of October 1, 1890, the meteorological duties and the civilians and enlisted men specially engaged therein were, on July 1, 1891, transferred from the War Department to the Department of Agriculture, and were reorganised as the Weather Bureau of that Department. On the other hand, at the same time and by virtue of the same Act, many of the Lieutenants of the Corps and other officers of the Army, together with many of the observer-sergeants, were organised into a well-proportioned Signal Corps in the regular Army, with Gen. A. W. Greely as Chief Signal Officer. By this arrangement, the civilian meteorological and scientific duties now devolved upon the new Chief of the Weather Bureau and his subordinates, while the military duties remained with the Chief Signal Officer of the Army and the Signal Corps. Thus, the military and the scientific organisations were separated, but both thereby became permanent and better prepared for their respective duties.

In the Act of Transfer the scope and duties of the Weather Bureau, under the Secretary of Agriculture, are defined as follows:—

"The Chief of the Weather Bureau . . . shall have charge of the forecasting of weather; the issue of storm warnings; the display of weather and flood signals for the benefit of agriculture, commerce, and navigation; the gauging and reporting of rivers; the maintenance and operation of sea-coast telegraph lines, and the collection and transmission of marine intelligence for the benefit of commerce and navigation; the reporting of temperature and rainfall condi-

tions for the cotton interests; the display of frost and cold-wave signals; the distribution of meteorological information in the interests of agriculture and commerce; and the taking of such meteorological observations as may be necessary to establish and record the climatic conditions of the United States, or as are essential for the proper execution of the foregoing duties."

A few additional duties have been added since 1891, but all entirely in the spirit of the terms of this Act of Transfer. Thus, for instance, by the Appropriation Act of 1892 the Chief of the Weather Bureau was empowered to pay special attention to climatology in its relation to organic life, and in 1894 this was extended to include its relations to sanitary science, and these studies are now entrusted to a special section of the Bureau.

In 1898 an Act of Congress added to the duties of the Weather Bureau, which had hitherto been confined to the United States, a much larger field of observation, namely, the region which the West Indian hurricanes traverse before they enter the United States proper. In accordance with this law, telegraphic reporting stations have been established throughout the West Indies and the coasts of the Gulf of Mexico and Caribbean Sea, and our Daily Weather Map now extends from Trinidad and Barbados in the south-east to British Columbia in the north-west.

The first Chief of the Weather Bureau under the Secretary of Agriculture was Prof. Mark W. Harrington, who held that office from July 1, 1891, to June 30, 1895. He was succeeded, on July 1, 1895, by Prof. Willis L. Moore, who still continues in office.

2. The stations occupied by the Weather Bureau may be classified as follows:—

A. Regular stations occupied by one or more men respectively, whose whole time is given to the Government service. There are 149 of these. Each is furnished with one or more self-recording instruments, and would, therefore, be called a station of the first order according to the definition established by the International Meteorological Congress. Of these, 113 keep continuous registers of temperature; 105 of pressure; 71 of rainfall; 68 of sunshine; 135 of wind velocity; 90 of wind direction.

At many of these stations only one person is employed; at others, such as New York and Chicago, 6 or 8 are in constant attendance, owing to the innumerable demands on their time and attention. It is considered quite as important to diffuse our knowledge promptly and widely as it is to collect it accurately; therefore, in general, these stations must be located in cities and near the central telegraph offices and the Boards of Trade, newspapers, and other public centres. It is consequently impracticable to establish thermometers and rain-gauges near the ground; we have therefore chosen a free roof exposure, and often on a comparatively high building. Under these conditions, some of our stations, such as New York and Chicago, are located at unusually great altitudes above the ground, which conditions give them great advantages for general meteorological purposes, but some slight disadvantages with regard to local climatology.

B. Stations occupied by observers who ordinarily make one observation per day of temperature and rainfall, or the height of rivers and rainfall, and are paid a small sum for that particular observation. These may be classified as follows:—126 in the cotton region, observing temperature and rainfall; 129 in the corn and wheat region, observing temperature and rainfall; 124 in river valleys, observing river and rainfall; 38 in river basins, observing rainfall—total 417.

C. Unpaid voluntary observers, who generally record, at least, the daily maximum and minimum temperatures, the rainfall, wind and weather, and local thunderstorms. These receive no compensation in money, but, by way of

exchange, receive the Crop Bulletins, the Monthly Weather Review, and other publications of the Weather Bureau. There are about 3000 observers of this class; they are classified by States and organised as sections of the Climate and Crop Service of the Weather Bureau.

D. The 12 stations recently established in the West Indies generally belong to Class A, being equipped and manned entirely at the expense of the Weather Bureau; but it is contemplated to eventually make this an international service between the United States and the local authorites in the West Indies, analogous to the system of co-operation that has, for a long time, existed between the United States and Canada.

E. The system of stations reporting directly to the Surgeon-General of the U.S. Army, the Superintendent of the U.S. Life-Saving Service, the Southern Pacific R.R. Company, and other organisations also co-operate with the Weather Bureau.

F. From 1871 until 1887 the Weather Bureau had a steadily increasing number of voluntary co-operating observers among the navigators of all oceans, and daily weather maps of the Northern Hemisphere were prepared in order to study storm phenomena in the interests of meteorology and American commerce throughout the world. This work on the ocean was, however, by mutual consent, transferred by the Chief Signal Officer to the Hydrographer of the U.S. Navy; but the duty of forecasting storms for the benefit of commerce still devolves, by Law of Congress, upon the Chief of the Weather Bureau. In 1887 the marine observers reporting to the Weather Bureau numbered about 600, but, according to the latest reports of the Hydrographic Office, this number is now increased to several thousands. So far as these reports are needed by the Weather Bureau, they are promptly placed at our disposal by the Hydrographer of the U.S. Navy.

3. In November 1870 the daily weather bulletins of observations began to be published with the first day of the month, and the first prediction of storm winds was made on November 8 for the Lake region. Predictions were, at this time, restricted to storms, as contemplated in the original Act establishing a service "for giving notice . . . of the approach and force of storms." The regular weather "probabilities," so called for the first few years, began to be published, thrice daily, in February 1871; they included all interesting items of the weather, and eventually covered every portion of the country. This was weather forecasting, as distinguished from storm forecasting, and it is the success of this feature that has rendered the Weather Bureau indispensable to every citizen.

The verifications of these predictions have, in general, been quite satisfactory. Attempts have sometimes been made to express the correctness of the predictions by means of percentages, which may be stated about as follows:—

Regular daily forecast for each State for 36 hours in advance: weather 85 per cent, temperature 83 per cent.

General predictions for 48 hours in advance, when practicable: weather 81 per cent, temperature 75 per cent.

Local wind signals for 24 hours in advance, whenever occasion requires: cautionary signals 70 per cent, storm-wind signals 80 per cent, cold-wave signals 75 per cent.

Daily local river and flood predictions and special flood warnings, when occasion requires, 100 per cent.

The preceding percentages are those that result from the application of certain stringent rules adopted by the Forecast Division of the Weather Bureau in studying the works of different forecasters. It is, however, proper to say that many predictions which are marked low by these rules have been credited

with very high compliments by the public, and the percentages of success ascribed by unprejudiced persons outside of the service have always been much higher than those above given.

The popular appreciation of the work of the Weather Bureau depends largely upon the thoroughness and promptness with which its forecasts are brought to the attention of every one interested in the subject. There would be no popular support for the Bureau if it were not that every citizen, on many occasions during each year, has occasion to consult and profit by the published predictions. In order to distribute the forecasts promptly, the following methods are resorted to:—

(*a*) They are immediately given to the press for publication in all newspapers.

(*b*) They are telegraphed to about 150 Weather Bureau stations and 2000 forecast display stations, where they are displayed as bulletins or by means of flag signals.

(*c*) They are telegraphed to about 80 stations where daily maps are printed, and 20 stations where daily bulletins are printed, where they are immediately added to the maps and bulletins and posted up for public use throughout the city and neighbourhood; they are also printed at about 50 other stations, upon large postal cards, and mailed to about 40,000 post-offices, where they are properly displayed for public use. In all, about 64,000 public displays of weather forecasts are made daily.

(*d*) At all regular Weather Bureau stations telephone circuits are concentrated, and about 50,000 individual telephone subscribers obtain the latest forecasts at any moment by telephone.

4. The principal work of the Weather Bureau has always been recognised as the practical utilisation of the Daily Weather Map for purposes of weather prediction. The predictions are based upon a knowledge of the changes then going on in the atmosphere, as shown by the comparison of the daily weather maps. Only a small fraction of the force of the Bureau has been engaged in that class of work properly designated investigation. It was necessary first to collect the data on a large scale before it was possible to attack the problem of the laws of the movements of the atmosphere and its storms on a satisfactory comprehensive scale.

To this end, the first step consisted in the enlargement of the scope of the Daily Weather Map, so as to include the whole area of the United States and all details as to clouds, moisture, and other meteorological elements. The second step was to extend this map so as to cover the whole Northern Hemisphere, both as to oceans and continents; and daily maps of this character have been compiled ever since 1875, although they have not been published since 1885. A general summary of the results of this work was published in 1891, and again in 1892. This summary also forms a large element in the material for Buchan's monthly charts in the Reports of the Challenger Expedition.

The next step was to extend the range of observations as far northward as possible, to which end the stations at Point Barrow and Fort Conger were occupied in 1882-83. A similar extension southward has just been inaugurated in 1898, covering the Caribbean Sea.

A still more important extension of the service was inaugurated by the occupation of mountain stations at Mount Washington and Pike's Peak, which stations are now replaced by an extensive system of records from points a mile high by means of kites carrying self-registers. Of a very similar character is the extensive study made into the heights and motions of clouds.

The list of completed investigations includes about 600 papers, published principally as "bulletins" or special reports when the Bureau was under the Secretary of War, a list of which is given at pages 387-409 of the *Annual*

Report of the Chief Signal Officer of the Army for 1891; also, about forty larger reports and several hundred smaller published by members of the Weather Bureau since it has been under the direction of the Secretary of Agriculture. A printed list of the latter will be available in a few months.

5. The principal studies now in hand are those of Prof. F. H. Bigelow on the results of recent cloud work, and those of Prof. C. F. Marvin on the results of recent kite work.

6. The amount of the annual appropriation for the maintenance of the Weather Bureau must not be considered as in any sense of the word "for the support of science." Undoubtedly, meteorological science will derive much benefit from our work; but the appropriations are for specific matters of practical importance, and it is only incidentally that science can profit thereby. The Appropriation Bill for the fiscal year 1898-99 designated the following sums:—

Office of the Chief: Salaries	$153,340
,, ,, Fuel, lights, repairs	8,000
,, ,, Contingent	8,000
General Expenses, outside of Washington: Salaries	382,195
,, ,, ,, Rents, Telegraphy, Printing, etc.	382,967
Special building at Sault Ste. Marie, Mich.	3,000
,, Bismarck, N. Dakota	3,000
Special Printing at the Government Printing Office	10,000

In proportion to the area and population, the number of regular stations wholly supported by the Government and the general expense of the Service is seen to be by no means large, and probably not in excess of the relative amounts spent by several other nations.

A careful analysis will show that only a small proportion of the appropriation above quoted can be used for scientific investigation as such, the rest being devoted to the maintenance of a system of observations, predictions, and publications which constitutes a practical application of whatever may be known of meteorological science. The observations and maps that are made for this practical purpose constitute a daily meteorological survey, and belong to the observational branch of this science. No provision is specifically made for scientific investigations, except investigations in sanitary and climatological questions. Whatever may be accomplished by the members of the Service is additional to the practical duties prescribed by Congress. The amount of attention given to the development of meteorology, considered as the study of the mechanics of the atmosphere, must therefore depend upon the exigencies of the Service and the judgment of the Chief as to the relative importance of the various fields of work. At the present moment, special importance is attached to the extension of the daily map over the West Indies and Mexico, as also to the preparation of the daily map of conditions prevailing to the height of a mile above sea-level. When this last work shall have been satisfactorily accomplished, we shall have the data for discussing the motions of the air, the reduction to sea-level, the formation of cloud and rain, and other important questions in meteorological science.

XXXIV.—The Argentine Republic.

Oficina Meteorológica, Cordoba.—Mr. W. G. Davis, Director.

1. The Argentine Meteorological Office was founded at the instigation of Dr. B. A. Gould, who arrived in this country in 1870, for the purpose of establishing the National Astronomical Observatory. Finding that scarcely any exact data regarding the climatic conditions existed, he proposed to the Government

the enlistment of voluntary observers throughout the Republic, and to furnish them with the necessary instruments for obtaining reliable observations; at the same time offering his services gratuitously for the organisation and direction of the first efforts of the Service.

The suggestions of Dr. Gould met with a favourable response from the National Executive, and resulted in an Act of Congress, passed in October 1872, authorising the founding of the present Meteorological Office.

During the following months the Central Office was installed in the building of the Astronomical Observatory, and circulars sent out soliciting the co-operation of those who were willing to make observations.

In the year 1873 instruments were issued to 13 stations, at which observations were made at 7 a.m., 2 p.m., and 9 p.m.

During the year 1878 self-registering instruments were secured for the Central Office, which gave hourly values of the barometric pressure, temperature, humidity, direction and velocity of the wind. In the years following, new stations were added, and older ones abandoned; the latter largely due to change of residence of the observers, or to their inability or disinclination to continue the routine of their self-imposed task. On the retirement of Dr. Gould at the end of 1884, observations had been made at 52 different stations. A few of these showed uninterrupted series extending from 8 to 12 years, but the larger number were limited to periods varying from 2 to 4 years; and at that date systematic observations were received from 18 stations. Four volumes had been published containing the results and discussion of observations from 17 widely distributed regions.

At the beginning of 1885 the Meteorological Office passed to its present direction, and in May of the same year the Central Office was transferred to its own building, which had been specially constructed with regard to the requirements of the Service, and situated 600 feet to the south of the Astronomical Observatory. An entire new equipment of modern instruments was substituted for those formerly in use.

In subsequent years the work has been extended to embrace all branches of meteorological work corresponding to a Central Station, and the number of contributing stations gradually increased.

2. At the present time the organisation comprises:—

(1) Central Station fully equipped, with the exception of the self-registering magnetic instruments, which have not yet been installed, owing to lack of funds for the construction of the building and cellars. Observations of the elements not registered automatically are made every two hours during the day and night.

(2) 10 stations supplied with the Richard instruments for the automatic registration of the barometric pressure, temperature, and humidity. The control observations are made three times a day, as well as those of the clouds and the direction and velocity of the wind. Some of these are furnished with sunshine recorders, solar and earth thermometers, and evaporating dishes. The most northerly of these stations is at Asuncion, Paraguay, at the opposite side of the river from Argentine territory, and the most southerly on Staten Island, near Cape Horn.

(3) 44 stations at which regular observations of the principal elements are made at 7 a.m., 2 p.m., and 9 p.m.

(4) 136 stations at which the rainfall is measured, and a few of these are supplied with maximum and minimum thermometers.

Since 1885 complete sets of instruments have been set up at 80 stations, and over 300 rain-gauges distributed.

3. No extensive weather predictions have been attempted, as a large proportion of the stations are, or until recently have been, so remote from telegraphic

communication that only meagre data could be had for this purpose. Nearly all the violent storms that sweep the Argentine Pampa are formed in the Cordilleras between the 40th and 45th parallels of latitude, several hundred miles distant from the nearest telegraph line. The observations from the stations situated in this region do not reach us till months after they have been made.

4. The publications of the Office have been principally confined to the discussion of the observations made at the central and contributing stations. The 14 published volumes contain the results of 43 series of observations. Nearly all the periodic variations are expressed in analytic terms deduced by means of the Bessel sine formula. No special investigations have been separately published.

5. Investigations are now in progress for determining the influence of the wind direction and velocity on the amount of evaporation from the surface of water exposed in the different systems of evaporators in general use, such as the copper and glass dishes, Wild's balance, and tanks; also a comparison of soil temperature as shown by the ordinary earth thermometers and by rheostats with their electrodes buried at the same depth as the thermometer bulbs. In the present investigations these depths range from 0·10 to 3·75 meters.

6. The amount of grant from the Government has varied greatly in these last years, owing to the fluctuations in the value of the paper currency. The appropriations for this year amount to $35,940 (paper dollars) which at the present gold premium is equal to £3365. The following is the distribution for the different objects:—

Salaries of Director and Assistants	£1680
,, Observers	562
Inspection of Stations, Publications, acquisition of Instruments, etc.	1123
	£3365

It is only in the past three years that the observers in charge of first and second order stations have received salaries—$10 (paper) per month.

The above amounts in number of dollars are practically the same as formerly when gold was at par, so that in these past years the annual grants have been reduced from 50 to 75 per cent.

XXXV.—Jamaica.

Weather Service, Kingston.—Mr. Maxwell Hall, Government Meteorologist.

1. The Jamaica Weather Service was established in 1880 in order to have the usual instruments read and recorded at Kingston, the chief town in Jamaica, to encourage the registration of the rainfall throughout the island, and to give warning of approaching hurricanes.

Mr. Robert Johnstone, F.R.Met.Soc., has assisted me from the first. He undertook the registration of the instruments in Kingston, and thereby allowed me to return to my private residence, the Kempshot Observatory, near Montego Bay. These places are 78 miles apart, on the line of usual approach of cyclones along the Caribbean Sea; consequently, by an exchange of telegrams, Mr. Johnstone and I have been able to make out fairly well what any cyclone was doing, and to issue the proper telegraphic notice or warning.

At times, during the absence of Mr. Johnstone, I have been assisted by Mr. J. F. Brennan, who has shown unusual skill in improving self-registering instruments.

The registration of the rainfall has been encouraged by issuing a *Monthly*

Weather Report to all the contributors, of whom there are about 200; and among these Weather Reports are published any special reports or investigations.

2. The only first class station is Kingston, elevation 50 ft.

The second class stations are:—Hill Gardens, 4907 ft.; Castleton Gardens, 496 ft.; Negril Point Lighthouse, 33 ft.

The third class stations are:—Hope Gardens, 600 ft.; Stony Hill Reformatory, 1400 ft.; Morant Point Lighthouse, 8 ft. (P. W. D.); and Montego Bay, 160 ft., where I now live, instead of at the Observatory, in order to attend to judicial duties.

There is also a screen with maximum and minimum thermometers, and a rain-gauge of special construction, on top of the Blue Mountain Peak, 7423 ft., the highest point of Jamaica. The instruments are read at the end of each month by a messenger from the Hill Gardens.

The observations made and results obtained at all the above stations are published more or less fully in the *Monthly Weather Reports*.

3. With regard to storm warnings, according to a revised list 38 depressions have passed within barometric range of Jamaica since the Service was established; but many were so clearly due to cyclones at a distance, which were not coming our way, that we cannot claim to have seriously dealt with more than 20 or so. At any rate, no mistake has yet been made, and the hurricane signals have been ordered up only thrice: August 18, 1880, August 20, 1886, and September 15, 1889. Forecasts for *daily* rainfall were fairly successful, but could not reach the agricultural community generally. Forecasts for *monthly* rainfall were commenced in 1884 and discontinued in 1886. Of these, 80 per cent were correct: but the subject required more attention than I could give it, and when a large rainfall was forecasted for May 1896, that month proved unusually dry, and when, with an average forecast for June 1896, heavy rains fell June 5 and 6, and floods did enormous damage, it was clearly time to stop forecasting.

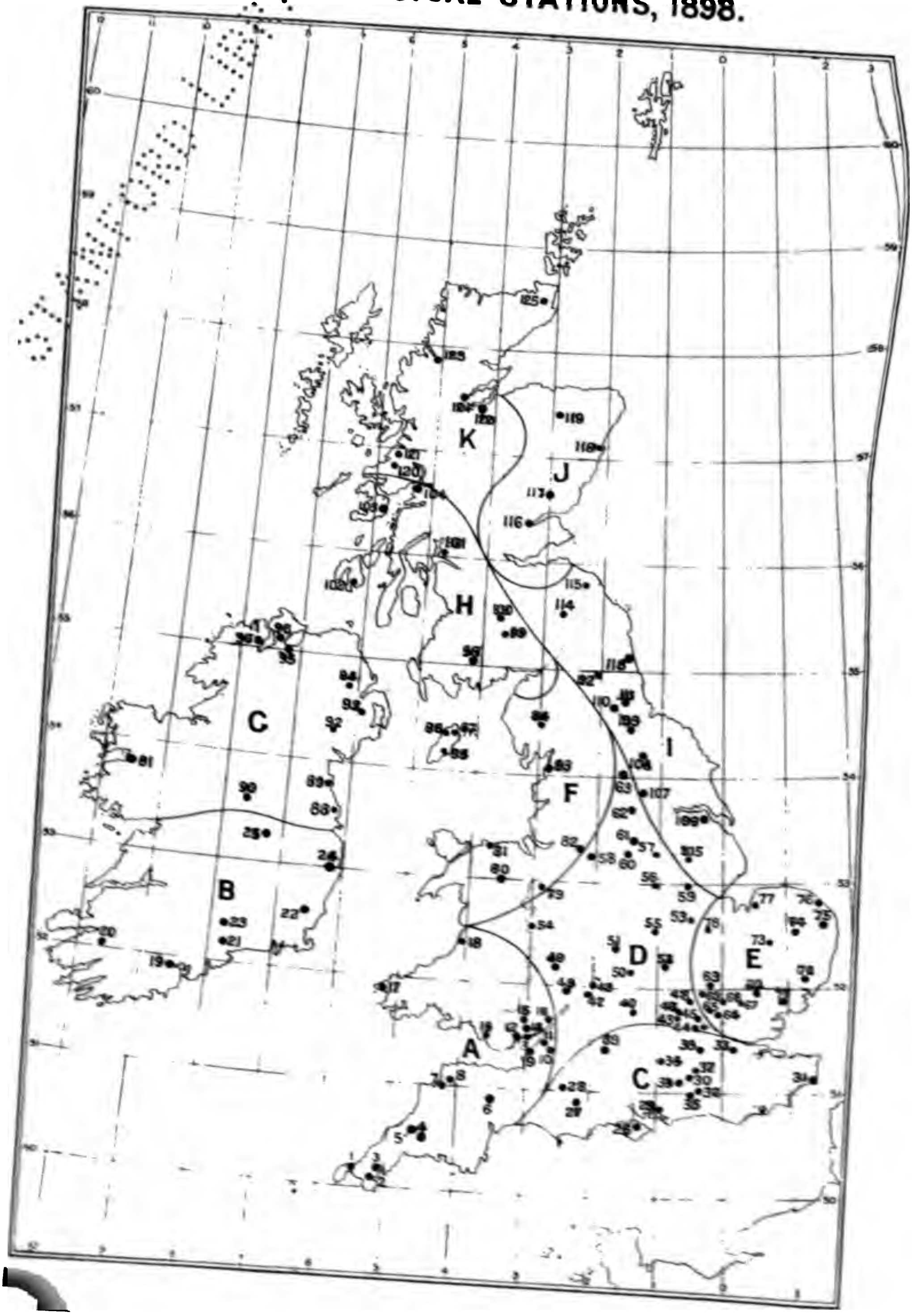
4. The investigations completed have been: Diurnal Variation of the Barometer for every hour for each month of the year; Mean Barometric Pressures; Classification of Clouds; Cyclones of 1880; Cyclones generally, as observed in Jamaica; Tropical Cyclones; Earthquakes; Health of Kingston; Protection of Buildings from Lightning; Magnetic Variation; Rainfall Maps; Rainfall and the Sunspot Period; Meteorological Results; Temperature and Pressure; Tides in Kingston Harbour; and Winds in Kingston.

5. The only investigations I have on hand at present with respect to the Weather Service are connected with cyclones—theoretical and practical.

6. I receive a subsidy of £150 a year from the Government to maintain the Weather Service, and I have to pay my assistants, and to find my own instruments; but the Government print the Weather Reports, supply the Service with stationery, and send round what weather telegrams may necessary.

Note.—The Editors regret to have to state that, by letter dated December 13, 1898, Government Grant to Mr. Hall has been discontinued.

MAP SHOWING POSITION OF THE PHENOLOGICAL STATIONS, 1898.



For the Names of the Stations see List of Observers, Page 141.

REPORT ON THE PHENOLOGICAL OBSERVATIONS FOR 1898.

By EDWARD MAWLEY, F.R.H.S., Secretary.

(Plate III.)

[Read February 15, 1899.]

Thanks to the kind assistance given by some of the corresponding Societies connected with the British Association, additional observers have been obtained during the past year for several of the districts where they were much needed. The total number of observers is now 127, or 17 more than in the previous year.

The following are the changes that have taken place in the observing stations since the appearance of the last report. No returns were received from Cardiff in District A; Bexhill-on-Sea and Swanley in District C; St. Albans (Addiscombe Lodge), Radlett, and Evesham in District D; Wormley in District E; and Claxby and Cambois in District I. On the other hand, new stations have been started at Cappagh and Marlfield in District B; Chesham, Farnborough, Thornhaugh, Sheffield, Sandbeck, Horbury, and Ripley in District D; Broxbourne, Hatfield, Sawbridgeworth, Market Weston, Brunstead, Clenchwarton, and Peterborough in District E; Alderley Edge in District F; Port Ellen, Lochbuie, and Duror in District H; South Milford, Willington, Blyth, Lilliesleaf, and Chirnside in District I; and Horse Cross in District J.

Advantage has been taken of the fact that the mean results for two more years are available since the actual averages for the different plants were first employed in 1896, to recalculate these averages. So that the averages given in the present Report are based upon the data available for the past 8 years, instead of, as in the two previous Reports, upon the records for the first 6 of those 8 years. An endeavour has also been made to improve the "approximate averages" for the plants in those districts where the records were not sufficiently complete during the whole of the 8 years for reliable averages to be made out for them.

The Winter of 1897-98.

Taking the winter as a whole, the temperature throughout the British Isles was uniformly high. The warmest month was January, when the variation in mean temperature from the average ranged between + 4°·8 in the south-west and east of England to + 6°·5 in the west of Scotland. December was almost everywhere a wet month, but in most districts less than an average quantity of rain fell during January and February. January proved gloomy, but in the other two months of the quarter the records of sunshine were unusually good.

Seldom has there been a winter in so many respects favourable to the farmer. The ground not only continued singularly warm throughout the season, but was at the same time during the greater part of it very dry. The young corn, which had been sown in a perfect seed-bed in the autumn, was thus enabled to make steady

growth without becoming in any but the most forward districts "winter proud." The rain which fell in December was welcomed, as it rendered the soil firm round the young plants, and any superfluous moisture that there happened to be passed readily away from the neighbourhood of their roots, owing to the absorbent condition of the subsoil. One of the most noteworthy features of the season was the unusually early date at which the planting of spring corn began. In fact, by the end of February a great deal of wheat had already been sown in the southern half of England, and that too under the most favourable conditions possible. The weather remained so mild and the grass in the meadows so plentiful, that all kinds of stock in many parts of the country lived practically out of doors all the winter. At the end of the season nothing could well be more promising than the appearance of all such winter crops as wheat, oats, winter barley, rye, clover, cabbages, kale, and rape, while the grass in the pastures remained almost as green as in an ordinary spring.

TABLE I.—MEAN RESULTS, WITH THEIR VARIATIONS FROM THE 8 YEARS' AVERAGE (1891-98), FOR THE THIRTEEN PLANTS IN THOSE DISTRICTS WHERE THERE HAVE BEEN SUFFICIENT OBSERVATIONS TO WARRANT COMPARISONS BEING MADE.

YEARS.	Eng. S.W.		Eng. S.		Eng. Mid.		Eng. E.		Eng. N.W.	
	Day of Year.	Variation from Average.	Day of Year.	Variation from Average.	Day of Year.	Variation from Average.	Day of Year.	Variation from Average.	Day of Year.	Variation from Average.
		Days.		Days.		Days.		Days.		Days.
1891	144	+12	144	+11	150	+12	147	+12	150	+10
1892	139	+ 7	138	+ 5	144	+ 6	143	+ 8	147	+ 7
1893	118	-14	122	-11	125	-13	123	-12	128	-12
1894	126	- 6	130	- 3	135	- 3	127	- 8	137	- 3
1895	139	+ 7	138	+ 5	141	+ 3	138	+ 3	144	+ 4
1896	125	- 7	128	- 5	132	- 6	130	- 5	134	- 6
1897	130	- 2	132	- 1	136	- 2	132	- 3	142	+ 2
1898	133	+ 1	135	+ 2	138	0	136	+ 1	141	+ 1
Mean	132	...	133	...	138	...	135	...	140	...

Explanation of the Dates in the Tables.

1- 31 are in	January.	182-212 are in	July.
32- 59 ,,	February.	213-243 ,,	August.
60- 90 ,,	March.	244-273 ,,	September.
91-120 ,,	April.	274-304 ,,	October.
121-151 ,,	May.	305-334 ,,	November.
152-181 ,,	June.	335-365 ,,	December.

No record of this remarkable winter would be complete without some mention of the heavy snowstorm which visited the south-west of England on the night of February 21-22. The counties of Hants, Dorset, Devon, and Somerset were alone seriously affected. In these counties, over an area about 60 miles long by 20 miles wide, the average depth of snow ranged from one to two feet deep. Unlike the memorable snowstorm of January 1881, the flakes were large and wet, and consequently great damage was done to trees and evergreen shrubs. An interesting account of this snowstorm will be found in the March number of *Symons' Meteorological Magazine* for 1898.

The destruction of many kinds of injurious insects must have been very great. Indeed, in the opinion of Mr. R. M'Lachlan, F.R.S., the eminent entomologist, "the winter of 1897-98 should have been one of the most fatal on record for insects whose larvæ or pupæ hybernate." In stating this, Mr. M'Lachlan was no doubt referring more especially to the frosty period which suddenly set in at the end of February, after a long spell of unseasonably warm weather.

For the gardens the season was unusually favourable. There was always a plentiful supply of green vegetables in the kitchen garden, and many autumn flowering plants continued in bloom until quite late in December, and in the warmer districts throughout the whole winter. No doubt the reason why the fruit trees did not, in such a warm winter, become dangerously forward was on account of the dryness of the ground, and the unusual extent to which their flowering shoots had ripened in the autumn. The forward condition of vegetation does not appear to have been confined to any one part of the country, but to have been general throughout the British Isles.

The winter was such a very mild one that all the earliest flowering plants came into blossom much in advance of their usual time. For instance, the hazel, taking the British Isles as a whole, was as much as 17 days early, and the coltsfoot as much as 16 days early.

The song-thrush was first heard 17 days earlier than its mean date. While the honey-bee was first seen to visit flowers 11 days earlier than usual.

All the above four dates are the earliest recorded during the 8 years covered by the present series of Phenological Reports.

The Spring.

This was almost everywhere rather a cold spring. The only unseasonably warm month was April, when the mean temperature was in all districts more or less in excess of the average. March proved dry, but during the rest of the season the fall of rain was in excess of the mean. The distribution of sunshine varied considerably, the departures from the average ranging from − 37 hours in the south of England, to + 72 hours in England north-west.

The cold nights in March (which, except in Scotland and the north of Ireland, was the coldest month of the year) gave a timely check to all the autumn-sown farm crops, and prevented them from becoming unduly forward. Throughout the season the land continued in splendid order for tillage operations, so that in the backward as well as in the early districts spring corn was got in under unusually favourable conditions. At the end of the quarter the cereals did not, as a rule, present quite as promising an appearance as at the beginning of it. In no part of the kingdom, however, except Scotland, where the oat crop deteriorated considerably during the spring, was the difference anything but slight. On the other hand, the grass lands, which in April looked chilled and backward, made such surprising growth during May, that it soon became evident that the yield of hay must everywhere be an unusually bountiful one.

There was in all parts of the country a magnificent show of blossom

on the fruit trees, but the cold North-easterly winds which prevailed in the latter half of April, and again in May, prevented all but a small proportion of the flowers setting their fruit. In few localities, however, did there occur any but very moderate frosts, so that to the injurious effects of these cold winds must, I think, be added the lack of vigour in

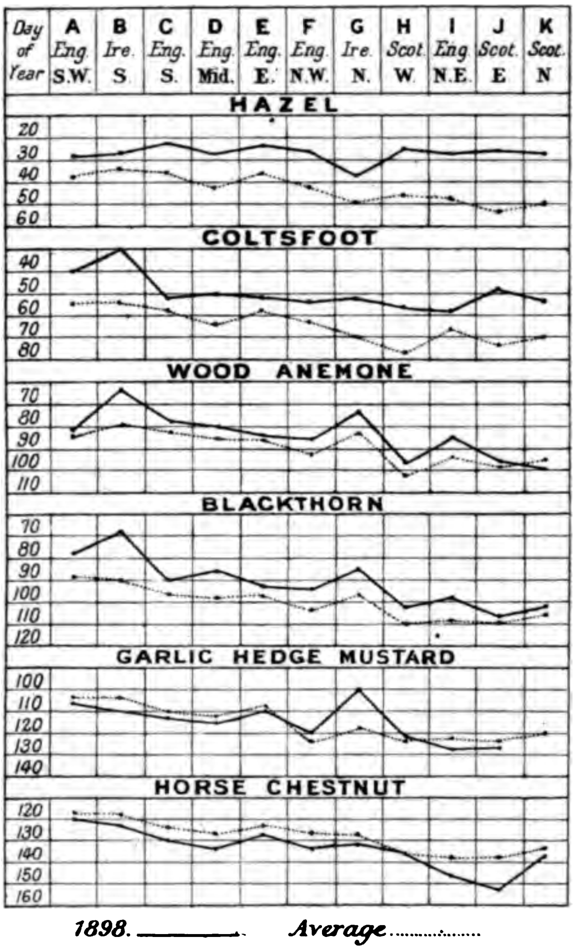


FIG. 1.—Mean dates (day of year) of flowering of plants in 1898 as compared with the eight years' average 1891-98.

the trees themselves, owing to the remarkably dry condition for the time of year of the subsoil.

The wood anemone flowered 5 days in advance of its average date, while the blackthorn was 10 days early; but after this time the cold weather in March began to make itself felt, so that all the other spring-flowering plants on the list were behind their usual time—the garlic hedge mustard being 1 day late, the horse-chestnut 5 days late, and the hawthorn 3 days late.

The spring migrants could not well have been more punctual, the swallow arriving on its mean date, the cuckoo 1 day late, the nightingale 1 day early, and the flycatcher 3 days early.

The wasp made its appearance 1 day behind its usual time, the small white butterfly 4 days late, and the orange-tip butterfly 5 days late.

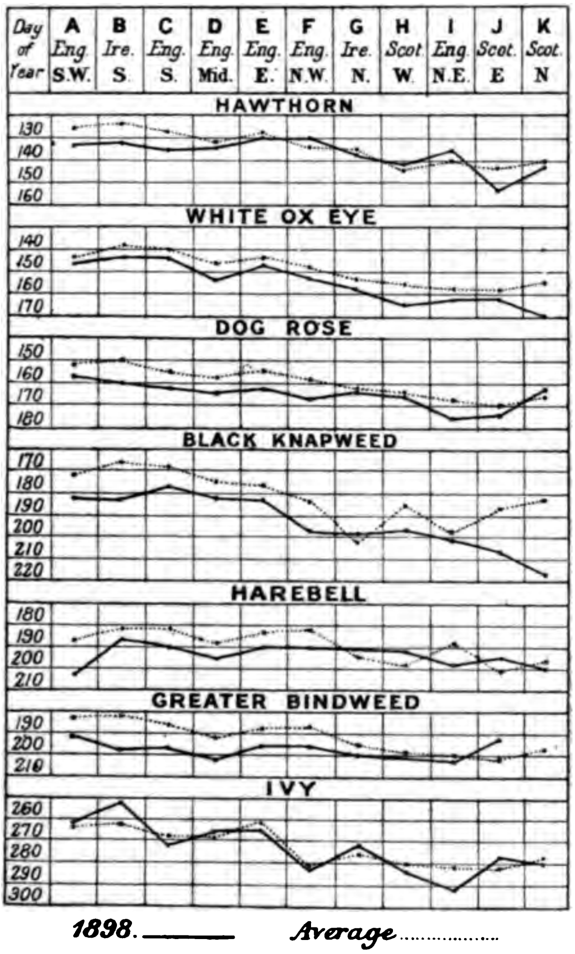


FIG. 2.—Mean dates (day of year) of flowering of plants in 1898 as compared with the eight years' average 1891-98.

The Summer.

The mean temperature of the quarter, taking the country as a whole, was about seasonable, June being rather cold, July warm in some districts and cold in others, while August was everywhere unusually warm. Throughout the British Isles there was a deficient rainfall, and particularly was this the case in the south-west and south of England.

June proved in nearly all districts a dull month, July on the other hand being as unusually sunny, while the records for August were extremely variable.

The cereals, which had, if anything, lost ground during the spring months, rapidly recovered under the drier and more genial atmospheric conditions which prevailed in June, and were once more as promising as could well be wished. No doubt the slow growth made during the spring had been, after all, beneficial both to the corn and grass, as it enabled them to become more firmly rooted. The yield of hay was everywhere a remarkably heavy one, and was harvested in splendid condition. As stated by Sir John Lawes, "the immense hay crop all over the country was probably due not only to the abundance of rain in May, but also to an unusual accumulation of nitrate within the soil during the previous autumn and the early months of the year, with much less than the usual amount of rain to wash it out." Fortunately that critical period in the growth of corn known as the "earing time" was characterised by dry and sunny weather. Indeed, although there were a good many cold nights in July, the days proved unusually warm, and the cereals, hastened by the dry state of the ground, ripened rapidly. In the warmer parts of our Islands a great deal of corn had been cut and carried before the end of August; and, favoured by the continued fine weather, was in most districts gathered in with a minimum amount of labour. Here and there, however, a good deal of the corn, which was unusually long in the straw, was beaten down by thunderstorms, and therefore required more care and trouble in harvesting. At Rothamsted, in Hertfordshire, the rainfall for the cereal year, ending August, is stated to have been the lightest since that of 1869-70, or for 28 years. The heat and drought, although suiting the corn crops, proved very trying to the turnips and pastures.

As one of our observers aptly remarks, "this was the best summer for farmers for many years, but the worst for gardeners." In June all garden plants made most satisfactory progress, but the hot and dry weather which followed checked their growth, particularly those on porous soils. Such early fruits as strawberries, gooseberries, currants, and raspberries, yielded well in most places, but the gathering season was short and the fruit as a rule small. Even before the end of the summer limes and other trees were already beginning on light soils to shed their leaves.

Few wasps were to be seen until August, when, in many parts of the country, they made their appearance in unusual numbers. Butterflies were scarce throughout the whole summer. Aphides of all kinds were undoubtedly the insect pests of the season, and amounted in most districts to a plague on fruit trees, roses, cabbages, etc. In some localities much damage was also done by caterpillars.

All the summer flowering plants on the list came into blossom behind their average dates, the white ox-eye being 6 days late, the dog-rose 5 days late, the black knapweed 11 days late, the harebell 4 days late, and the greater bindweed 5 days late.

The meadow-brown butterfly made its appearance 8 days later than usual.

The Autumn.

This was a singularly warm season in all parts of the kingdom, the departure in mean temperature from the average ranging between + 2°·4 in the north of Scotland, to + 4°·2 in the south of England. Except in Ireland and in the east and north of Scotland, there was a deficient rainfall. September proved exceptionally sunny, but in October and November there was a scanty record of sunshine in most districts.

The harvest proceeded rapidly and without check in nearly all parts of the country, and proved remarkably bountiful both in the yield of grain and of straw. Indeed, the only drawback appears to have been the difficulty in finding sufficient hands to assist in getting together so heavy a crop. But the dry weather, which so greatly favoured the ingathering of the cereals, proved very trying to other farm produce. Indeed, seldom after harvest time has the prospect in England generally threatened to be as serious, owing to the great heat and persistent drought. This drought, at all events as far as farm and garden crops are concerned, may be said to have lasted from the beginning of June until the middle of October, or for four and a half months. In all parts of the British Isles, except the south of Ireland, there was a deficient rainfall during that period. But only throughout England (if we except the north-western district), and in the east of Scotland, was the dry weather sufficiently continuous to cause the pastures for many weeks together to remain brown and bare, and to arrest entirely the growth of turnips and swedes. What made the prospect so very unpropitious in the dry districts at the beginning of October, was that not only were all crops at a standstill, but the ground had become so dry and hard that there appeared no chance of sowing any corn before the winter set in.

When, however, shortly afterwards a change to wet weather took place, it was found that the soil had been left by the drought in such a friable condition, that all arrears of farm work were rapidly made up. Moreover, the warmth imparted to the ground by the previous unseasonable heat, caused the grain when sown to germinate quickly. Indeed, by the end of the season, almost as much corn had appeared above ground as if it had been planted at the usual time in an ordinary autumn.

In the same surprising manner, the meadows and pastures very quickly recovered from their parched condition, and were soon as green as before the dry weather set in, so that in a short time there was again ample keep for the sheep and cattle. The foregoing remarks are of course only applicable to the area covered by the drought, for in the north-west of England and throughout the greater part of Scotland and Ireland the pastures remained green during the whole of the summer and autumn.

In the dry area before mentioned, the growth of plants in the gardens was equally stunted, raspberries and celery being among the chief sufferers in the kitchen garden. Apples and pears ripened rapidly, but the fruit was mostly small. Owing to the absence of any keen frosts, the gardens were, for the time of year, unusually gay with flowers until late in the season—dahlias and chrysanthemums being especially good. In many places much damage was done to cabbages, etc., by the caterpillar of the large white butterfly.

Some deciduous trees shed their leaves very early, but the majority retained their foliage much longer than usual. So many leaves had become shrivelled by the heat and drought that the autumn tints were in many places shorn of much of their beauty. Wild fruits were as a rule plentiful, and especially blackberries and the hips of the wild roses.

According to a preliminary statement for Great Britain issued by the Board of Agriculture, the estimated yield per acre of wheat, barley, and beans in 1898 exceeded that for any other year since official statistics as to produce were first collected in 1884, while those of oats and peas have only twice before been exceeded in the same 15 years. In Ireland the cereal crops were also remarkably good, especially that of oats. Taking the United Kingdom as a whole, the corn harvest began 3 days behind the mean date for the previous 7 years. Hay was almost everywhere a very heavy crop. The yield of mangolds was about average, while peas and turnips were, except in parts of Scotland, scanty crops. Potatoes were above average in Scotland and Ireland and in the south-west and north-west of England, but elsewhere yielded indifferently.

There were fair crops of all the small fruits, but those of apples, pears, and plums were, generally speaking, much under average.

The ivy came into flower at its average date.

The last swallows took their departure 1 day earlier than their usual time.

The Year.

The weather of the past Phenological year was, taken as a whole, exceedingly warm and dry. The winter and autumn, and the latter half of the summer, proved unusually warm, but during the spring and early summer rather low temperatures prevailed. Wild plants blossomed much in advance of their average dates until about the end of March, but after that time until the close of the flowering season they were mostly late in coming into bloom.

Favoured by the rains in May, the crop of hay was everywhere a remarkably heavy one. Then followed a severe drought, which, as far as its influence on vegetation is concerned, may be said to have lasted without a break throughout nearly the whole of England from the beginning of June until the middle of October. Consequently during a great part of that period the grass in the pastures was dried up, while the yield of roots turned out a very scanty one. On the other hand, the dry season suited the cereals admirably, and especially the wheat, which produced a singularly abundant crop of grain and straw. The yield of barley was nearly as exceptional, while that of oats was an unusually good one in England and Ireland, but fell short of the average in Scotland. There was a splendid crop of potatoes in Ireland and in parts of Scotland, but elsewhere the yield was on the whole moderate and the tubers small. In all districts, however, they were remarkably free from disease.

Apples, pears, and plums flowered abundantly, but the cold winds prevailing at the time, and the reduced vitality of the trees through the dry condition of the subsoil, caused an irregular set of fruit; so that in all parts of the kingdom, the crops of these fruits were as a rule much below average. On the other hand, there were fair crops of all the small fruits.

TABLE II.—List of the Stations with the Names of the Observers.

Station.	County.	Height above Sea-level.	Observer.
A		Ft.	
1. Marazion	Cornwall	40	F. W. Millett.
2. Mawnan	Cornwall	200	Miss R. Barclay.
3. Falmouth	Cornwall	190	Miss E. Willmore.
4. Liskeard	Cornwall	400	S. W. Jenkin, C.E.
5. Altarnon	Cornwall	600	C. U. Tripp, M.A., F.R.Met.Soc.
6. Tiverton	Devon	270	Miss M. E. Gill.
7. Westward Ho	Devon	130	Miss Patterson.
8. Barnstaple	Devon	90	T. Wainwright.
9. Sidcot	Somerset	200	W. F. Miller.
10. Long Ashton	Somerset	280	Miss H. H. Dawe.
11. Clifton	Gloucester	300	G. C. Griffiths, F.E.S.
12. Penarth	Glamorgan	120	G. A. Birkenhead.
13. Castleton	Glamorgan	80	F. G. Evans, F.R.Met.Soc.
14. Bridgend	Glamorgan	90	H. J. Randall, Junr.
15. Bassaleg	Monmouth	125	W. J. Grant, F.R.H.S.
16. St. Arvans	Monmouth	360	Miss M. Peake.
17. St. Davids	Pembroke	220	W. P. Propert, LL.D., F.R.Met.Soc.
18. Aberystwith	Cardigan	30	J. H. Salter, D.Sc.
B			
19. Cork	Cork	100	R. A. Phillips.
20. Killarney	Kerry	100	Ven. Archdeacon Wynne, D.D.
21. Cappagh	Waterford	140	R. J. Ussher.
22. Ferns	Wexford	260	G. E. J. Greene, M.A., D.Sc., F.L.S.
23. Marlfield	Tipperary	...	R. Hunter.
24. Glendalough	Wicklow	460	Mrs. W. Wynne.
25. Geashill	King's County	280	Rev. Canon Russell.
C			
26. Bembridge	Isle of Wight	80	C. Orchard, F.R.H.S.
27. Blandford	Dorset	270	J. C. Mansell-Pleydell, F.G.S., F.L.S.
28. Buckhorn Weston	Dorset	290	Miss H. K. H. D'Aeth.
29. Havant	Hants	30	H. Beeston.
30. Muntham	Sussex	250	P. S. Godman, F.Z.S.
31. Dover	Kent	150	F. D. Campbell.
32. Chislehurst	Kent	360	Miss F. Duncan.
33. Coneyhurst	Surrey	600	J. Russell.
34. Churt Vicarage	Surrey	350	Rev. A. W. Watson.
34. Churt	Surrey	300	C. Criddle.
35. Chiddingfold	Surrey	230	Vice-Admiral Maclear, F.R.Met.Soc.
36. Winterfold	Surrey	580	R. Turvey.
37. Oxshott	Surrey	210	W. H. Dines, B.A., F.R.Met.Soc.
38. East Molesey	Surrey	40	Lady Jenkyns.
39. Marlborough	Wilts	480	E. Meyrick.
D			
40. Oxford	Oxford	200	F. A. Bellamy, F.R.Met.Soc.
41. Cheltenham	Gloucester	250	M. L. Evans.
42. Beckford	Gloucester	120	F. Slade, F.R.Met.Soc.
43. Chesham	Bucks	300	Miss G. Keating.
44. Watford	Herts	240	Mrs. G. E. Bishop.
45. St. Albans (The Grange)	Herts	380	Mrs. Hopkinson.
45. St. Albans (Worley Road)	Herts	300	H. Lewis.
46. Berkhamsted	Herts	400	Mrs. E. Mawley.
47. Harpenden	Herts	370	J. J. Willis.

TABLE II.—List of the Stations with the Names of Observers—*Continued.*

Station.	County.	Height above Sea-level.	Observer.
		Ft.	
48. Ross	Hereford	210	H. Southall, F.R.Met.Soc.
49. Leominster	Hereford	220	J. H. Arkwright.
50. Farnborough	Warwick	520	Miss D. J. G. Prater.
51. Ullenhall	Warwick	340	Mrs. Coldicott.
52. Northampton	Northampton	320	H. N. Dixon, M.A., F.L.S.
53. Thornhaugh	Northampton	90	Rev. H. Slater.
54. Churchstoke	Montgomery	550	P. Wright, F.R.Met.Soc.
55. Thurcaston	Leicester	250	Rev. T. A. Preston, M.A., F.R.Met.Soc.
56. Beeston	Notts	210	G. Fellows.
57. Hodsock	Notts	60	Miss Mellish, F.R.H.S.
58. Macclesfield	Cheshire	500	J. Dale.
59. Belton	Lincoln	200	Miss F. H. Woolward.
60. Sheffield	Yorks (W.R.)	450	Miss E. F. Smith.
61. Sandbeck	Yorks (W.R.)	150	G. Summers.
62. Horbury	Yorks (W.R.)	100	J. Burton.
63. Ripley	Yorks (W.R.)	240	Rev. W. T. Travis.
E			
64. Broxbourne	Herts	120	Rev. H. P. Waller.
65. Hatfield	Herts	300	T. Brown.
66. Hertford	Herts	140	W. Graveson.
67. Sawbridgeworth	Herts	350	H. S. Rivers.
68. Hitchin	Herts	220	A. W. Dawson, M.A.
69. Ashwell	Cambridge	260	H. G. Fordham.
70. Bocking	Essex	240	H. S. Tabor, F.R.Met.Soc.
71. Lexden	Essex	90	Miss Carver.
72. Sproughton	Suffolk	30	Rev. A. Foster-Melliar.
73. Market Weston	Suffolk	150	Rev. E. T. Daubeney.
74. Tacolneston	Norfolk	190	Miss E. J. Barrow.
75. Brundall	Norfolk	70	A. W. Preston, F.R.Met.Soc.
76. Brunstead	Norfolk	30	Rev. M. C. H. Bird.
77. Clenchwarton	Norfolk	10	Rev. C. U. Manning.
78. Peterborough	Northampton	30	J. W. Bodger.
F			
79. Ellesmere	Shropshire	340	Miss D. F. Jebb.
80. Palé	Merioneth	600	T. Ruddy.
81. Conway	Carnarvon	190	A. T. Johnson.
82. Alderley Edge	Cheshire	300	W. H. Pepworth.
83. Claughton	Lancashire	80	Mrs. Green
84. Ambleside	Westmoreland	260	Miss M. L. Hodgson.
85. Cronkbourne	Isle of Man	110	A. W. Moore. J. Murphy.
86. Orry's Dale	Isle of Man	70	Miss C. M. Crellin.
87. Sulby	Isle of Man	80	H. S. Clarke, F.E.S.
G			
88. Ardgillan	Dublin	210	Capt. E. R. Taylor, F.R.Met.Soc.
89. Piperstown	Louth	320	Miss E. Smith.
90. Edgeworthstown	Longford	270	J. M. Wilson, M.A.
91. Westport	Mayo	10	J. M. McBride.
92. Loughbrickland	Down	350	Rev. H. W. Lett, M.A.
93. Saintfield	Down	310	Rev. C. H. Waddell, M.A.
94. Antrim	Antrim	70	Rev. W. S. Smith.
95. Altnafoyle	Londonderry	450	T. Gibson.
96. Ballynagard	Londonderry	30	Miss A. M. Campbell.
97. Ramelton	Donegal	200	Miss K. Swiney.

TABLE II.—LIST OF THE STATIONS WITH THE NAMES OF OBSERVERS—*Continued.*

Station.	County.	Height above Sea-level.	Observer.
H		Ft.	
98. New Galloway	Kirkcudbright	450	T. R. Bruce.
99. Thornhill	Dumfries	300	J. Fingland.
100. Jardington	Dumfries	100	J. Rutherford.
101. Helensburgh	Dumbarton	100	Miss Muirhead.
102. Port Ellen	Isle of Islay	10	T. F. Gilmour.
103. Lochbuie	Isle of Mull	20	J. Dudgeon.
104. Duror	Argyll	20	R. Macgregor.
I			
105. Doddington	Lincoln	90	Rev. R. E. Cole.
106. Great Cotes	Lincoln	30	J. Cordeaux.
107. South Milford	Yorks (W.R.)	70	J. B. Close.
108. Thirsk	Yorks (N.R.)	120	A. B. Hall.
109. East Layton	Yorks (N.R.)	570	Mrs. E. O. Maynard Proud.
110. Willington	Durham	390	Rev. W. T. Wyley.
111. Durham	Durham	350	H. J. Carpenter.
112. Corbridge-on-Tyne	Northumberland	200	A. W. Price.
113. Blyth	Northumberland	20	S. Dunnett.
114. Lilliesleaf	Roxburgh	530	General Sprot.
115. Chirnside	Berwick	400	C. Stuart, M.D.
J			
116. Horse Cross	Perth	...	T. M. M'Gregor.
117. Kirriemuir	Forfar	250	T. M. Nicoll.
118. Aberdeen	Aberdeen	40	P. Harper.
119. Newmill	Banff	350	J. Ingram.
K			
120. Invermoidart	Inverness	60	S. M. Macvicar.
121. Roshven	Inverness	40	H. Blackburn.
122. Beauly	Inverness	60	A. Birnie.
123. Inverbroom	Ross	50	The late Sir J. A. Fowler, Bart.
124. Dingwall	Ross	10	J. P. Smith, M.D.
125. Watten	Caithness	150	Rev. D. Lillie.

The numbers before the names of the stations refer to their position on the map of the stations, Plate III.

OBSERVERS' NOTES.

DECEMBER 1897.—*Clifton* (A)—25th. Geraniums, Gloire de Dijon roses, oxlips, etc., still in flower. *Glendalough* (B)—4th. Nasturtiums on the house flowering freely, until cut by last night's frost. *Geashill* (B)—25th. Cydonia Japonica, monthly roses, and many other flowers are still in flower in the Rectory garden. *Churt Vicarage.* (C)—25th. Many flowers still in blossom, including roses, laurustinus, and winter jassamine. 29th. Gathered a well-opened bud of the tea-rose Rubens. *Beckford* (D)—11th. Winter aconite in flower. Taking their average dates for the previous 15 years, all early flowers were from a fortnight to a month earlier than usual. *Berkhamsted* (D)—24th. Last rose of the year destroyed by frost, same day as last year but 10 days later than the average for the previous 12 years. *Ambleside* (F)—1st. Pink campion, herb-robert, and ragwort still in flower.

TABLE III.—DATE (DAY OF YEAR) OF FIRST FLOWERING OF PLANTS, 18

STATION.	Hazel.	Coltsfoot.	Wood Anemone.	Blackthorn.	Garlic Hedge Mustard.	Horse-chestnut.	Hawthorn.	White Ox Eye.	Dog Rose.	Black Knapweed.	Harebell.	Greater Bind-weed.
A												
Marazion	28	30	...	76	...	...	125	147	154	190	...	188
Mawnan	18	55	...	50	*128*	124	139	158	152	188	...	201
Falmouth	28	30	91	43	115	99	142	*107*	161	192	...	181
Liskeard	42	...	99	61	...	...	...	...	...	...	...	...
Altarnon	54	*82*	100	98	102	132	150	161	173	198	206	210
Tiverton	17	26	78	80	111	128	133	153	161	168	...	191
Westward Ho	...	...	...	91	96	97	132	136	157	198	...	200
Barnstaple	13	46	81	70	100	124	129	148	145	172	208	183
Sidcot	...	34	59	98	112	122	135	137	147	...	...	...
Long Ashton	6	34	70	86	98	105	119	...	137	...	*168*	190
Clifton	31	...	...	94	...	125	128	...	154	...	206	...
Castleton	22	22	72	71	107	113	130	138	159	179	199	191
Bridgend	58	...	...	93	102	136	142	...	...	...	...	...
Bassaleg	22	29	81	82	107	115	126	134	160	164	...	172
St. Arvans	23	61	80	90	111	128	135	153	158	173	201	...
St. Davids	...	49	...	*114*	...	122	126	153	...	184	200	195
Aberystwith	26	58	...	58	107	124	124	131	159	177	...	...
B												
Cork	26	19	47	72	...	129	124	129	...	...	...	...
Killarney	36	...	79	69	...	116	125	149	...	190	187	189
Ferns	29	41	60	67	...	110	125	147	156	168	...	191
Marlfield	28	...	...	51	...	...	...	...	...	...	...	...
Glendalough	26	...	71	75	...	124	139	139	...	185	...	206
Geashill	14	...	...	74	...	132	140	153	164	187	...	206
C												
Bembridge	21	20	...	96	114	114	128	134	161	185	...	...
Blandford	21	41	78	88	125	132	141	145	169	177	181	170
Buckhorn Weston	22	24	65	95	101	122	130	133	159	175	...	202
Havant	36	63	81	79	108	138	139	136	152	160	...	188
Muntham	11	56	71	79	109	126	126	139	150	163	...	...
Dover	...	...	...	77	...	127	143	...	169	187	...	...
Chislehurst	4	43	70	91	113	125	135	144	159	184	203	205
Coneyhurst	27	77	82	98	123	135	133	152	161	181	192	*166*
Churt Vicarage	13	75	92	101	111	136	140	151	166	182	182	199
Churt	6	77	94	97	106	126	130	151	159	178	186	201
Chiddingfold	25	25	70	94	116	128	129	144	161	182	...	212
Winterfold	20	...	84	93	...	143	150	*172*	...	...	196	...
Oxshott	39	...	...	101	114	136	134	...	...	...	...	...
East Molesey	44	59	...	82	113	127	128	142	164	184	183	200
Marlborough	20	50	61	87	120	133	134	150	160	169	194	200
D												
Oxford	...	...	...	...	...	128	135	...	...	...	...	...
Cheltenham	16	49	58	75	117	128	137	146	153	177	205	...
Beckford	26	17	74	70	111	128	126	133	150	178	190	185
Chesham	...	...	...	...	...	*146*	143	152	...	...	...	203
Watford	18	...	90	88	116	135	127	...	...	...	193	206
St. Albans (The Grange)	23	59	...	...	106	131	134	151	162	178	198	214

TABLE III.—DATE (DAY OF YEAR) OF FIRST FLOWERING OF PLANTS, 1898—*Continued.*

STATION.	Hazel.	Coltsfoot.	Wood Anemone.	Blackthorn.	Garlic Hedge Mustard.	Horse-chestnut.	Hawthorn.	White Ox Eye.	Dog Rose.	Black Knapweed.	Harebell.	Greater Bind-weed.	Ivy.
Berkhamsted . .	48	31	95	99	109	136	145	146	158	187	198	196	277
Harpenden . .	20	63	79	96	118	133	133	145	163	180	196	198	...
Ross . . .	22	21	...	80	108	126	124	148	...	...	...	...	...
Leominster . .	30	71	73	49	...	135	142	140	168	...	...	194	...
Farnborough .	16	31	80	93	112	133	119	156	160	188	204	218	280
Ullenhall . .	6	*10*	71	98	...	135	132	156	163	197	195	...	278
Northampton .	34	40	60	90	113	132	128	161	162	186	...	...	251
Thornhaugh .	42	61	84	75	115	...	121	...	156	...	185	...	255
Churchstoke .	40	64	91	98	125	134	...	...	160	...	...	191	...
Thurcaston . .	50	74	87	76	106	139	127	162	166	179	199	220	271
Beeston . .	31	55	...	99	*141*	142	138	164	165	173	...	...	...
Hodsock . .	7	41	75	58	110	124	127	160	161	181	199	183	268
Macclesfield .	28	60	89	114	138	143	146	161	175	189	191	193	273
Belton . .	27	41	62	79	120	129	127	160	153	171	183	213	262
Sheffield . .	27	78	76	...	...	142	142	162	180	*216*	209	...	...
Sandbeck . .	...	...	...	...	...	134	136	157	181	...	...	...	273
Horbury . .	...	38	108	...	129	*163*	145	159	*133*	169	196	207	...
Ripley . .	...	...	91	91	98	131	148	165	173	194	...	...	264
E													
Broxbourne . .	23	61	79	94	...	...	...	...	...	...	...	...	253
Hatfield . .	...	77	105	...	...	128	126	...	163	...	...	...	...
Hertford . .	30	40	72	76	86	130	122	142	160	184	187	205	261
Sawbridgeworth .	...	...	...	...	...	134	145	...	...	...	...	...	291
Hitchin . .	22	37	...	...	105	125	112	135	145	189	187	197	...
Ashwell . .	20	58	...	79	...	...	126	...	156	...	...	...	268
Bocking . .	24	41	97	92	112	124	129	159	166	183	196	204	...
Lexden . .	14	53	77	77	105	118	127	...	161	...	...	183	...
Sproughton . .	17	43	62	97	108	129	131	143	167	...	...	...	...
Market Weston .	...	...	...	...	124	132	135	148	164	183	...	193	264
Tacolneston .	27	...	...	...	103	119	133	...	...	...	...	...	...
Brundall . .	34	...	77	104	114	128	134	153	167	...	...	190	...
Brunstead . .	...	...	99	108	115	129	139	...	162	178	190	209	...
Clenchwarton .	...	...	...	98	114	134	135	...	172	...	...	191	...
Peterborough .	...	...	94	97	122	133	132	154	158	...	...	...	...
F													
Ellesmere . .	...	65	93	...	102	...	...	...	...	...	...	...	...
Palé . . .	33	68	100	98	128	141	143	159	167	197	188	206	293
Conway . .	18	...	...	...	...	...	112	...	...	...	...	...	...
Alderley Edge .	26	62	96	*119*	128	...	127	153	...	...	198	...	...
Claughton . .	...	41	89	99	...	...	...	155	...	...	...	...	...
Ambleside . .	18	54	52	78	122	138	132	144	...	...	...	...	278
Cronkbourne .	...	36	...	...	...	128	138	153	...	...	...	186	280
Orry's Dale . .	35	...	...	100	...	125	128	*172*	169	...	184	...	275
G													
Ardgillan . .	37	41	102	...	...	130	140	163	...	195	...	209	278
Piperstown . .	50	...	...	78	...	130	138	...	162	197	...	197	292
Edgeworthstown .	...	...	...	82	...	137	138	149	...	...	...	...	...
Westport . .	...	...	*31*	88	...	114	128	...	...	...	...	...	256

TABLE III.—DATE (DAY OF YEAR) OF FIRST FLOWERING OF PLANTS, 1898—*Continued.*

STATION.	Hazel.	Coltsfoot.	Wood Anemone.	Blackthorn.	Garlic Hedge Mustard.	Horse-chestnut.	Hawthorn.	White Ox Eye.	Dog Rose.	Black Knapweed.	Harebell.	Greater Bind-weed.	Ivy.
Loughbrickland	28	*86*	97	91	...	144	147	161	161	*157*	...	194	...
Saintfield	...	36	...	...	...	129	...	...	...	...	...	...	...
Antrim	66	...	55	83	100	133	136	159	165	198	...	209	264
Altnafoyle	58	65	...	111	...	138	138	...	166	204	...	...	...
Ballynagard	24	...	48	56	...	118	...	...	162	...	...	190	272
Ramelton	*85*	62	61	93	...	136	139	...	...	*217*	...	202	...
H													
New Galloway	31	...	107	104	...	145	147	167	...	...	...	...	...
Thornhill	27	27	106	...	...	...	...	...	...	...	...	...	...
Jardington	28	69	73	102	...	143	140	163	165	197	191	...	...
Helensburgh	12	56	100	106	121	124	*117*	...	...	...	...	...	...
Port Ellen	...	66	92	94	...	...	...	...	...	...	...	...	...
Lochbuie	...	...	105	...	...	...	147	...	...	...	...	...	...
Duror	...	60	86	105	...	...	128	...	...	...	...	...	283
I													
Doddington	29	60	79	98	112	129	132	161	170	...	...	186	266
South Milford	26	65	105	104	...	141	129	...	...	...	...	...	...
Thirsk	...	...	71	72	116	139	127	159	161	189	209	...	286
East Layton	...	...	...	...	...	...	...	...	...	...	...	...	305
Willington	...	65	...	116	...	145	131	174	183	...	...	186	296
Durham	...	66	...	111	...	152	151	*184*	180	...	197	...	...
Corbridge-on-Tyne	21	67	78	104	145	153	147	162	174	212	196	218	286
Blyth	37	41	...	...	...	...	...	...	...	...	...	...	...
Chirnside	*60*	46	91	91	140	161	135	152	181	*161*	193	222	305
J													
Horse Cross	...	*101*	...	...	...	...	146	...	...	...	...	...	...
Kirriemuir	...	64	96	104	...	...	...	160	...	199	188	...	...
Aberdeen	...	57	*113*	...	...	154	156	158	173	206	208	...	268
Newmill	26	26	98	109	127	152	158	165	175	213	189	192	288
K													
Invermoidart	39	...	103	...	...	...	141	...	...	212	...	...	280
Roshven	31	60	98	97	...	139	127	164	152	211	...	...	282
Beauly	26	69	96	106	...	140	150	167	169	...	199	...	...
Inverbroom	19	17	...	...	...	...	...	...	...	...	...	...	...
Dingwall	25	66	101	102	...	133	144	164	167	...	200	...	279
Watten	...	*89*	...	...	...	...	150	183	...	228	...	...	...

The dates in *italics* have not been taken into consideration when calculating the means given in Table IV.

JANUARY 1898.—*Mawnan* (A)—1st. Great tit heard. 14th. Clematis with young shoots 2 feet long. More than 50 garden flowers in bloom, including Banksia roses, camellias, and rhododendrons. *Falmouth* (A)—15th. Second flowering of wild strawberry, stitchwort, celandine, etc. 17th. Camellia in full bloom out of doors. *Altarnon* (A)—1st. Lesser celandine in flower. *Tiverton* (A)—3rd. Roses still in flower *St. Arvans* (A)—1st. Cydonia Japonica in flower.

TABLE IV.—Mean Dates (Day of Year) for the First Flowering of Plants in 1898, and their Variations from the Eight Years' Average (1891-98).

Plants.	A England, S.W.			B Ireland, S.			C England, S.			D England, Mid.		
	1898.	Average for 8 Years.	Variation from Average.	1898.	Average for 8 Years.	Variation from Average.	1898.	Average for 8 Years.	Variation from Average.	1898.	Average for 8 Years.	Variation from Average.
Hazel	28	38	− 10	27	*34*	− 7	22	36	− 14	27	42	− 15
Coltsfoot	40	55	− 15	30	*54*	− 24	51	59	− 8	50	64	− 14
Wood Anemone	81	84	− 3	64	*79*	− 15	77	82	− 5	80	86	− 6
Blackthorn	78	89	− 11	68	*90*	− 22	90	96	− 6	85	99	− 14
Garlic Hedge Mustard	106	104	+ 2	...	*104*	...	113	110	+ 3	115	112	+ 3
Horse-chestnut	120	118	+ 2	122	*118*	+ 4	130	124	+ 6	133	128	+ 5
Hawthorn	132	127	+ 5	131	*124*	+ 7	135	128	+ 7	134	131	+ 3
White Ox Eye	146	143	+ 3	143	*138*	+ 5	143	140	+ 3	154	147	+ 7
Dog Rose	156	152	+ 4	160	*150*	+ 10	161	155	+ 6	164	158	+ 6
Black Knapweed	182	172	+ 10	183	*167*	+ 16	177	169	+ 8	182	175	+ 7
Harebell	203	188	+ 15	187	*181*	+ 6	190	181	+ 9	196	189	+ 7
Greater Bindweed	191	182	+ 9	198	*181*	+ 17	197	186	+ 11	202	191	+ 11
Ivy	262	263	− 1	253	*262*	− 9	272	269	+ 3	268	269	− 1
Mean for the 13 Plants	133	132	+ 1	131*	*131**	Av.*	135	133	+ 2	138	138	Av.

Plants.	E England, E.			F England, N.W.			G Ireland, N.			H Scotland, W.		
Hazel	23	37	− 14	26	42	− 16	38	50	− 12	25	47	− 22
Coltsfoot	51	59	− 8	54	64	− 10	51	70	− 19	56	78	− 22
Wood Anemone	85	86	− 1	86	92	− 6	73	83	− 10	96	102	− 6
Blackthorn	92	97	− 5	94	103	− 9	85	97	− 12	102	110	− 8
Garlic Hedge Mustard	110	109	+ 1	120	123	− 3	100	*118*	− 18	121	*122*	− 1
Horse-chestnut	128	123	+ 5	133	127	+ 6	131	128	+ 3	137	137	Av.
Hawthorn	130	128	+ 2	130	134	− 4	138	136	+ 2	141	143	− 2
White Ox Eye	148	144	+ 4	153	149	+ 4	158	153	+ 5	165	*156*	+ 9
Dog Rose	162	155	+ 7	168	159	+ 9	163	162	+ 1	165	164	+ 1
Black Knapweed	183	177	+ 6	197	184	+ 13	199	202	− 3	197	*185*	+ 12
Harebell	190	184	+ 6	190	182	+ 8	...	*195*	...	191	*199*	− 8
Greater Bindweed	196	188	+ 8	196	188	+ 8	200	*195*	+ 5	...	*199*	...
Ivy	267	262	+ 5	282	281	+ 1	272	*276*	− 4	283	*280*	+ 3
Mean for the 13 Plants	136	135	+ 1	141	141	Av.	134*	139*	− 5*	140*	144*	− 4*

Plants.	I England, N.E.			J Scotland, E.			K Scotland, N.			British Isles.		
Hazel	28	49	− 21	26	*54*	− 28	28	*50*	− 22	27	44	− 17
Coltsfoot	59	66	− 7	49	*74*	− 25	53	*70*	− 17	49	65	− 16
Wood Anemone	85	93	− 8	97	*99*	− 2	100	*95*	+ 5	84	89	− 5
Blackthorn	99	109	− 10	107	*110*	− 3	102	*106*	− 4	91	101	− 10
Garlic Hedge Mustard	128	*123*	+ 5	127	*124*	+ 3	...	*120*	...	116	*115*	+ 1
Horse-chestnut	146	139	+ 7	153	*138*	+ 15	137	*134*	+ 3	134	129	+ 5
Hawthorn	136	140	− 4	153	*144*	+ 9	142	*140*	+ 2	137	134	+ 3
White Ox Eye	162	158	+ 4	161	*158*	+ 3	170	*154*	+ 16	155	149	+ 6
Dog Rose	175	168	+ 7	174	*170*	+ 4	163	*166*	− 3	165	160	+ 5
Black Knapweed	201	198	+ 3	206	*187*	+ 19	217	*183*	+ 34	193	182	+ 11
Harebell	199	189	+ 10	195	*201*	− 6	200	*197*	+ 3	194	*190*	+ 4
Greater Bindweed	203	*200*	+ 3	192	*201*	− 9	...	*197*	...	197	*192*	+ 5
Ivy	291	*281*	+ 10	278	*282*	− 4	280	*278*	+ 2	273	*273*	Av.
Mean for the 13 Plants	147	147	Av.	148	*149*	− 1	145†	*143†*	+ 2†	140	140	Av.

* For 12 Plants. † For 11 Plants.

\+ indicates the number of days later than the average date.
− ,, ,, ,, earlier ,, ,,
Av. ,, average date (1891-98).
The dates in *italics* are approximate averages.

6th. Winter aconite in flower. *Aberystwith* (A)—6th. Cydonia Japonica in flower. 8th. Daphne mazereon in flower. 25th. Frog spawn first seen. *Marlfield* (B)—Not nearly as many winter migrants as usual during the last three months. *Geashill* (B)—23rd. Thrush's nest seen. *Bembridge* (C)—24th. Nasturtiums, coronillas, and many other flowers still in blossom. *Havant* (C)—22nd. Daphne mazereon in flower. *Churt* (C)—1st. Willow in full bloom, the earliest date of flowering I can remember. *Berkhamsted* (D)—7th. Winter aconite in flower, 17 days earlier than its average date of first flowering in the previous 9 years, and earlier than in any of those years. *Cheltenham* (D)—2nd. Winter aconite in flower. *Macclesfield* (D)—28th. I enclose a twig of my hazel bush ; I have never seen it in bloom in January before. *Sheffield* (D)—27th. Cydonia Japonica in flower. *Lexden* (E)—20th. Winter aconite in flower. *Ambleside* (F)—27th. Daphne mazereon in flower. *Ardgillan* (G)—Many queen wasps seen. *Ballynagard* (G)—22nd. A blackberry still in bloom. *New Galloway* (H)—20th. Winter aconite in flower. *Jardington* (H)—The pastures throughout the month have been quite green. *Chirnside* (H)—In 50 years I have only twice before seen primroses in flower in January. *Dingwall* (K)—Buds on hawthorn breaking into leaf in sheltered places. *Watten* (K)—22nd. Winter aconite in flower. 31st. The following flowers are either continuing in bloom or coming into flower in my garden—rather an exposed one—stocks, wallflowers, marigolds, and anemones.

FEBRUARY.—*Marazion* (A)—Wild fowl of all kinds have been exceedingly scarce. *Mawnan* (A)—9th. Self-sown seedling nasturtiums up. *Falmouth* (A)—16th. Ripe wild strawberry seen. *Barnstaple* (A)—28th. The number of species of wild plants observed in flower up to date was 37, the average for the past 10 years being 20. *Long Ashton* (A)—8th. Elms in blossom. *Bridgend* (A)—21st. 6 ins. of snow on the ground. *St. Arvans* (A)—13th. Chiffchaff singing. *Aberystwith* (A)—Rose campion and herb-robert have flowered all through the winter. 12th. Elm in blossom. *Marlfield* (B)—22nd and 23rd. Much damage done to tender vegetation by frost. *Bembridge* (C)—4th. Prunus Pisardi in flower. *Churt Vicarage* (C)—20th. Coronilla glauca in full flower. *Cheltenham* (D)—19th. Cydonia Japonica in flower. *Sheffield* (D)—12th. Strawberry-leaved cinquefoil in flower—a very early date. *Ardgillan* (G)—Many summer flowering plants have continued in bloom here and there throughout the winter, including dandelions, charlock, and germander speedwell. *Edgeworthstown* (G)—13th. Prunus Pisardi in flower. *Loughbrickland* (G)—Mignonette in flower all the winter. *Saintfield* (G)—Flowers remained on roses, primroses, etc., in the gardens all the winter. *Antrim* (G)—Have not been without flowers in my garden the whole of the winter.

MARCH.—*Marazion* (A)—Owing to the mildness of the winter in the Midlands, market gardeners here have lost heavily by their early broccoli crops, as their usual markets were fully supplied with vegetables grown in their own neighbourhood. *Instow* (A)—14th. I send you two ripe wild strawberries gathered to-day. *Sidcot* (A)—24th. A terrible blizzard from North and North-east. Comparatively little snow, but the wind lasted for several days. Many large plants of wallflower, which were in full bloom, were shrivelled up as if burnt. *Buckhorn Weston* (C)—15th. Chiffchaff first heard. *Havant* (C)—27th. Wryneck first heard. *St. Albans* (D)—30th. Chiffchaff first heard. *Conway* (F)—20th. Robin's nest with 6 eggs. *Ambleside* (F)—15th. Grey wagtail first seen. *Loughbrickland* (G)—31st. Chiffchaff first heard.

APRIL.—*Altarnon* (A)—16th. Chiffchaff heard. *Long Ashton* (A)—Fruit blossom early but scanty. Comparatively little set for no apparent reason, as the weather was not unfavourable. *Bassaleg* (A)—17th. Village sycamore in full leaf. *Chislehurst* (C)—13th. First willow-wren and wryneck. 17th. First redstart and chiffchaff. *Coneyhurst* (C)—24th. Sand-martin first seen. *Churt*

TABLE V.—DATE (DAY OF YEAR) OF SONG AND MIGRATION OF BIRDS, AND FIRST APPEARANCE OF INSECTS, 1898.

Station.	Song.	Migration.					Insects.				
	Song-Thrush first heard.	Swallow first seen.	Cuckoo first heard.	Nightingale first heard.	Flycatcher first seen.	Swallow last seen.	Honey Bee.	Wasp.	Small White Butterfly.	Orange Tip Butterfly.	Meadow Brown Butterfly.
A											
Marazion	11	104	109	...	...	283	91	...	71	143	184
Mawnan	...	...	...	...	...	...	23	...	95	138	177
Falmouth	...	105	111	...	147	...	23	...	91	135	...
Liskeard	2	99	102	...	...	...	44	...	79	135	92
Altarnon	3	104	105	...	113	280	32	44	109	135	118
Tiverton	...	...	112	...	...	...	80	...	...	...	...
Westward Ho	15	107	111	...	165	263	21	*208*	106	...	209
Sidcot	...	105	107	111	133	292	72	...	*135*	135	...
Long Ashton	2	106	104	116	119	...	2	39	...	...	...
Clifton	...	107	113	...	...	...	22	29	98	162	...
Penarth	...	...	...	...	...	...	98	150	98	127	182
Castleton	3	97	99	...	142	291	18	98	106	107	184
Bridgend	18	106	107	...	...	...	79	...	107	...	...
Bassaleg	3	106	112	113	129	279	8	14	98	102	127
St. Arvans	2	107	106	...	125	284	31	113	108	127	174
St. Davids	39	103	112	...	...	271	71	...	115	144	163
Aberystwith	...	103	115	...	125	289	...	...	106	126	167
B											
Cork	3	...	124	...	...	...	111	...	111	114	159
Killarney	...	100	...	...	...	271	70	122	94	125	...
Cappagh	...	101	113	...	141	315	...	115	118	111	...
Ferns	2	103	113	...	...	273	80	90	103	126	106
Marlfield	8	...	...	...	...	...	26	21	...	...	...
Glendalough	9	99	118	...	...	263	6	...	114	127	124
Geashill	...	103	...	...	...	...	...	...	102	129	184
C											
Bembridge	1	94	107	104	...	322	24	22	98	170	173
Blandford	2	101	105	106	104	...	61	126	89	106	186
Buckhorn Weston	1	100	104	118	128	291	...	...	105	109	171
Havant	8	96	...	113	126	311	39	31	74	127	182
Muntham	7	101	104	104	129	282	60	116	92	142	...
Dover	...	105	...	...	...	298	...	...	...	...	...
Chislehurst	4	111	105	112	123	284	57	107	107	...	192
Coneyhurst	15	110	108	104	130	...	75	106	77	156	...
Churt Vicarage	6	102	107	108	116	283	22	137	103	127	180
Churt	4	103	105	106	129	...	2	78	*122*	124	171
Chiddingfold	...	104	100	104	101	280	4	134	107	107	182
Winterfold	23	104	105	104	...	293	...	80	...	141	...
Oxshott	10	104	106	114	...	289	...	...	...	...	...
East Molesey	1	113	110	111	...	276	31	126	93	141	...
Marlborough	22	99	110	...	134	...	...	...	91	129	183
D											
Oxford	7	98	...	...	...	...	...	...	102	...	...
Cheltenham	2	107	105	...	145	290	31	128	113	135	191
Beckford	...	102	106	107	130	292	12	113	108	143	...
Chesham	...	...	...	...	...	...	...	143	...	150	...
Watford	10	105	103	106	...	287	...	...	95	...	...
St. Albans (The Grange)	...	102	106	110	...	...	...	...	106	...	...
St. Albans (Worley Road)	8	105	105	105	...	...	...	...	...	126	...

TABLE V.—DATE (DAY OF YEAR) OF SONG AND MIGRATION OF BIRDS, AND FIRST APPEARANCE OF INSECTS, 1898—*Continued.*

STATION.	Song.	Migration.					Insects.				
	Song-Thrush first heard.	Swallow first seen.	Cuckoo first heard.	Nightingale first heard.	Flycatcher first seen.	Swallow last seen.	Honey Bee.	Wasp.	Small White Butterfly.	Orange Tip Butterfly.	Meadow Brown Butterfly.
Berkhamsted	13	96	107	110	*164*	291	31	94	90	142	191
Harpenden	16	115	105	117	...	...	...	121	107	79	...
Ross	3	...	106	...	132	...	21	20	109	114	...
Leominster	10	98	106	108	118	291	30	122	106	106	...
Farnborough	26	103	111	*136*	117	297	43	73	98	116	175
Ullenhall	8	103	105	112	133	289	10	21	...	...	...
Thornhaugh	9	101	110	108	132	274	...	...	...	147	...
Churchstoke	37	103	112	...	...	...	...	...	...	114	...
Thurcaston	...	...	116	...	...	...	...	...	127	147	...
Beeston	...	106	110	...	125	277	79	90	110	...	...
Hodsock	6	105	111	112	121	301	...	98	126	143	...
Macclesfield	21	106	113	...	...	281	...	...	...	...	...
Belton	1	102	113	109	138	...	13	97	103	113	...
Sheffield	9	116	121	...	...	...	106	136	127	...	...
Sandbeck	...	99	111	...	128	312	...	114	*159*	...	...
Horbury	...	107	121	...	128	306	...	...	135	...	...
Ripley	...	101	109	...	137	271	...	123	92	157	194
E											
Broxbourne	10	79	95	...	...	285	...	...	...	...	...
Hatfield	...	106	104	96	138	...	...	...	...	...	...
Sawbridgeworth	...	107	107	113	125	310	...	...	...	134	180
Hitchin	4	103	107	105	110	...	6	...	...	157	...
Ashwell	...	...	...	...	122	315	...	...	...	...	...
Bocking	...	118	113	112	...	...	...	...	...	...	...
Lexden	8	105	97	105	146	289	6	109	...	142	174
Sproughton	6	105	113	105	132	299	22	31	106	142	...
Market Weston	...	101	114	103	124	290	...	...	94	136	188
Tacolneston	...	103	...	112	...	...	...	...	...	127	...
Brundall	...	...	113	119	...	...	...	...	...	...	...
Brunstead	...	106	107	...	129	281	91	...	103	146	168
Clenchwarton	...	107	117	...	137	287	...	109	114	...	...
Peterborough	41	108	107	121	125	...	81	122	110	161	...
F											
Palé	7	101	107	127	...	268	55	113	126	143	189
Conway	1	...	...	...	...	...	31	111	...	...	...
Alderley Edge	20	115	112	...	133	...	...	134	127	158	...
Claughton	1	108	115	...	...	...	...	...	...	...	...
Ambleside	13	115	109	...	117	271	90	...	127	151	...
Cronkbourne	...	118	*138*	...	...	290	15	114	...	95	...
Orry's Dale	...	114	115	...	...	280	25	*186*	105	...	...
Sulby	30	109	111	...	...	304	54	92	99	...	159
G											
Ardgillan	1	96	118	...	...	274	...	1	104	125	158
Piperstown	3	104	114	...	...	295	68	97	102	111	166
Edgeworthstown	...	98	111	...	*158*	...	90	...	104	...	...
Westport	...	103	110	...	...	270	14	12	...	...	...
Loughbrickland	24	91	117	...	...	272	...	...	...	96	...
Saintfield	5	110	118	...	...	...	...	...	105	125	...
Antrim	...	104	117	...	...	...	79	...	99	108	...
Altnafoyle	...	118	126	...	...	...	...	...	120	125	189

TABLE V.—DATE (DAY OF YEAR) OF SONG AND MIGRATION OF BIRDS, AND FIRST APPEARANCE OF INSECTS, 1898—*Continued.*

Station.	Song.	Migration.					Insects.				
	Song-Thrush first heard.	Swallow first seen.	Cuckoo first heard.	Nightingale first heard.	Flycatcher first seen.	Swallow last seen.	Honey Bee.	Wasp.	Small White Butterfly.	Orange Tip Butterfly.	Meadow Brown Butterfly.
Ballynagard	...	107	123	...	...	286	...	...	...	...	183
Ramelton	1	109	116	...	138	281	12	123	111	121	...
H											
New Galloway	13	118	118	...	...	...	27	...	127	...	...
Thornhill	...	110	...	...	...	...	6	121	...	...	...
Jardington	7	116	118	...	...	...	...	138	121	...	181
Helensburgh	16	114	121	...	...	...	...	...	129	...	...
Port Ellen	...	...	117	...	...	...	...	...	...	...	...
Lochbuie	...	117	114	...	...	...	83	150	...	136	110
Duror	...	123	114	...	...	...	69	...	111	...	...
I											
Great Cotes	1	106	111	111	125	289	...	24	105	...	...
South Milford	10	112	113	...	...	...	34	101	...	158	...
Thirsk	8	105	120	...	...	278	...	105	103	144	...
East Layton	4	...	...	...	...	278	11	...	...	...	...
Durham	...	111	121	...	...	274	33	158	134	161	...
Corbridge-on-Tyne	43	113	121	...	...	276	...	114	...	...	...
Blyth	39	...	...	...	...	...	...	...	...	...	...
Lilliesleaf	46	...	...	...	...	299	42	...	...	...	...
Chirnside	14	106	120	...	125	292	...	120	...	...	...
J											
Horse Cross	...	*141*	*141*	...	...	...	101	141	135	...	...
Kirriemuir	...	107	118	...	...	...	15	90	...	...	...
Aberdeen	9	121	128	...	129	249	101	146	147	...	...
Newmill	60	132	123	...	...	258	68	110	114	167	163
K											
Invermoidart	20	...	121	...	...	...	...	116	112	...	106
Roshven	21	115	117	...	...	...	...	114	129	...	...
Beauly	*92*	132	124	...	*191*	243	70	128	151	...	233
Inverbroom	...	...	...	...	...	...	15	...	...	...	...
Dingwall	23	124	127	...	...	255	69	115	...	...	...
Watten	...	...	*160*	...	...	...	98	...	137	...	111
Mean Dates for the British Isles in 1898	12 Jan. 12th.	106 Apl. 16th	112 Apl. 22d	110 Apl. 20th	129 May 9th	285 Oct. 12th	46 Feb. 15th	98 Apl. 8th	108 Apl. 18th	130 May 10th	168 June 17th
Mean Dates for 1891-98	Jan. 29th.	Apl. 16th	Apl. 21st	Apl. 21st	May 12th	Oct. 13th	Feb. 26th	Apl. 7th	Apl. 14th	May 5th	June 9th

The dates in *italics* have not been taken into consideration when calculating the means for the British Isles.

***Vicarage* (C)—1st. Wryneck first heard. 13th. No wasp as yet seen. *Cheltenham* (D)—3rd. Chiffchaff heard. *Watford* (D)—22nd. Early potatoes blackened by frost under a sheltered wall. *St. Albans* (D)—15th. Wryneck first heard. *Berkhamsted* (D)—15th. Wild cherry in flower, 6 days in advance of its average date for the previous 12 years. *Harpenden* (D)—4th. Frog spawn first seen. *Market Weston* (E)—Spring migrants, generally speaking, much fewer than usual.**

TABLE VI.—ESTIMATED YIELD OF FARM CROPS IN 1898.

Description of Crop.	England.						Scotland.			Ireland.	British Isles.
	A S.W.	**C** S.	**D** Mid.	**E** E.	**F** N.W.	**I** N.E.	**H** W.	**J** E.	**K** N.	**B and G** S. and N.	
Wheat	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	...	O. Av.	O. Av.
Barley	O. Av.	O. Av.	O. Av.	O. Av.	Av.	Av.	Av.	Av.	...	O. Av.	O. Av.
Oats	O. Av.	O. Av.	Av.	O. Av.	Av.	U. Av.	U. Av.	U. Av.	U. Av.	O. Av.	O. Av.
Corn Harvest began, average Date	218 (Aug. 6)	216 (Aug. 4)	224 (Aug. 12)	223 (Aug. 11)	230 (Aug. 18)	234 (Aug. 22)	241 (Aug. 29)	241 (Aug. 29)	256 (Sept. 13)	231 (Aug. 19)	231 (Aug. 19)
Beans	...	Av.	O. Av.	O. Av.	Av.	O. Av.	O. Av.	O. Av.	...	...	O. Av.
Peas	...	O. Av.	U. Av.	U. Av.	O. Av.	O. Av.	...	U. Av.	...	Av.	O. Av.
Potatoes	O. Av.	U. Av.	U. Av.	Av.	O. Av.	U. Av.	O. Av.	U. Av.	Av.	O. Av.	O. Av.
Turnips	U. Av.	U. Av.	U. Av.	Av.	U. Av.	U. Av.	Av.	U. Av.	U. Av.	Av.	U. Av.
Mangolds	Av.	U. Av.	Av.	Av.	Av.	Av.	Av.	...	...	O. Av.	Av.
Hay (Permanent Pastures)	Much O. Av.	Much O. Av.	Much O. Av.	Much O. Av.	Much O. Av.	Much O. Av.	Av.	O. Av.	...	Much O. Av.	Much O. Av.
Hay (Clover, etc.)	Much O. Av.	Much O. Av.	Much O. Av.	Much O. Av.	Much O. Av.	Much O. Av.	Av.	O. Av.	...	Much O. Av.	Much O. Av.

The variations from the average for the above crops have been obtained from the returns which appeared in the *Agricultural Gazette*, August 8, 1898.

TABLE VII.—ESTIMATED YIELD OF FRUIT CROPS IN 1898.

Description of Crop.	England.						Scotland.	Ireland.	British Isles.
	A S.W.	**C** S.	**D** Mid.	**E** E.	**F** N.W.	**I** N.E.	**H, J, and K** W. E. and N.	**B and G** S. and N.	
Apples	U. Av.	U. Av.	U. Av.	U. Av.	U. Av.	Av.	Av.	U. Av.	U. Av.
Pears	U. Av.	U. Av.	U. Av.	U. Av.	U. Av.	U. Av.	U. Av.	U. Av.	U. Av.
Plums	U. Av.	U. Av.	U. Av.	U. Av.	U. Av.	U. Av.	U. Av.	U. Av.	U. Av.
Raspberries	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.
Currants	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.
Gooseberries	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.
Strawberries	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	Av.	O. Av.	O Av.

Symbols :—O. = Over. U. = Under. Av. = Average. This Table has been compiled from returns which appeared in the *Gardeners' Chronicle*, July 30, 1898.

TABLE VIII.—APPROXIMATE VARIATIONS FROM THE AVERAGE IN MEAN TEMPERATURE, RAINFALL, AND SUNSHINE, 1897-98.

WINTER 1897-98.

MONTHS.	Eng. S.W.	Ire. S.	Eng. S.	Eng. Mid.	Eng. E.	Eng. N.W.	Ire. N.	Scot. W.	Eng. N.E.	Scot. E.	Scot. N.
Temperature.											
	°	°	°	°	°	°	°	°	°	°	°
December	+2·4	+2·4	+2·6	+1·6	+1·8	+1·8	+1·6	+1·6	+1·8	+0·2	+0·2
January	+4·8	+5·3	+5·0	+5·0	+4·8	+5·5	+5·8	+6·5	+6·0	+6·0	+5·0
February	+1·5	+1·3	+2·3	+1·8	+2·0	+1·3	+1·3	+1·3	+1·8	+1·3	+0·5
Winter	+2·9	+3·0	+3·3	+2·8	+2·9	+2·9	+2·9	+3·1	+3·2	+2·5	+1·9
Rain.											
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
December	+2·3	+2·2	+0·8	+0·7	-0·2	+2·6	+1·4	+1·3	-0·1	+0·7	+0·8
January	-1·9	-1·1	-2·0	-1·5	-0·9	-0·1	-1·3	-1·9	-1·0	-1·4	+0·9
February	-0·7	-0·6	-0·6	-0·7	-0·7	+0·4	+1·1	+0·4	-0·7	-0·5	+3·0
Winter	-0·3	+0·5	-1·8	-1·5	-1·8	+2·9	+1·2	-0·2	-1·8	-1·2	+4·7
Sunshine.											
	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.
December	+20	+16	+21	+ 7	0	+15	+12	0	-11	0	+ 5
January	-14	-19	-14	-16	-22	-10	-20	-12	- 8	- 6	+ 5
February	+ 5	+11	+17	+19	+26	+31	+ 8	+29	+28	+24	- 1
Winter	+11	+ 8	+24	+10	+ 4	+36	0	+17	+ 9	+18	+ 9
SPRING 1898.											
Temperature.											
	°	°	°	°	°	°	°	°	°	°	°
March	-2·0	-1·8	-1·4	-1·8	-2·0	-1·8	-0·6	-0·4	-1·0	+0·2	-0·2
April	+0·8	+0·8	+0·5	+0·5	+0·5	+1·0	+1·5	+2·0	+1·8	+1·8	+2·0
May	-0·5	-0·8	-0·5	-1·8	-1·0	-1·0	-1·0	-0·8	-1·5	-2·0	-2·0
Spring	-0·6	-0·6	-0·5	-1·0	-0·8	-0·6	0·0	-0·3	-0·2	0·0	-0·1
Rain.											
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
March	-1·1	-2·0	-0·8	-1·0	-0·1	-0·9	-0·9	-1·6	-0·4	-0·9	+1·3
April	+0·2	+2·1	-0·6	+0·3	-0·4	+0·5	+1·1	+0·8	+0·9	+1·6	+1·3
May	+1·8	+0·3	+1·7	+0·8	+0·4	+1·6	+0·6	+0·1	+0·1	+0·1	+0·1
Spring	+0·9	+0·4	+0·3	+0·1	-0·1	+1·2	+0·8	-0·7	+0·6	+0·8	+2·7
Sunshine.											
	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.
March	+20	+17	- 6	- 1	- 5	+54	+36	+26	+24	+18	+17
April	+14	+ 3	+12	+12	+ 4	+ 5	+13	-22	-28	-32	-15
May	-25	-13	-43	-23	-29	+13	+18	+34	-17	+ 9	+31
Spring	+ 9	+ 7	-37	-12	-30	+72	+67	+38	-21	- 5	+33

+ indicates above the average, - below it.

TABLE VIII.—VARIATIONS FROM THE AVERAGE—*Continued.*

SUMMER 1898.

MONTHS.	Eng. S.W.	Ire. S.	Eng. S.	Eng. Mid.	Eng. E.	Eng. N.W.	Ire. N.	Scot. W.	Eng. N.E.	Scot. E.
					Temperature.					
	°	°	°	°	°	°	°	°	°	°
June . .	−0·8	−0·2	−0·6	−1·2	−1·0	−1·2	−0·8	−0·6	−0·8	−0·8
July . .	+1·0	+1·5	+0·3	−0·5	−1·8	−1·0	+0·3	−0·8	−1·5	−0·5
August . .	+1·4	+1·8	+1·8	+1·8	+1·4	+1·2	+1·4	+1·2	+1·6	+1·2
Summer . .	+0·5	+1·0	+0·5	0·0	−0·5	−0·3	+0·3	−0·1	−0·2	0·0
					Rain.					
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
June . .	−0·2	0·0	−0·6	−0·7	+1·0	+0·3	+0·5	−0·4	−0·5	−0·8
July . .	−2·4	−2·1	−1·7	−1·8	−1·6	−2·4	−2·4	−2·2	−1·7	−1·6
August . .	−0·7	+0·9	−1·5	−0·1	−1·1	+1·3	+0·2	+1·5	−0·6	−0·2
Summer . .	−3·3	−1·2	−3·8	−2·6	−1·7	−0·8	−1·7	−1·1	−2·8	−2·6
					Sunshine.					
	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.
June . .	+ 6	−22	−45	− 6	−51	−26	−45	−23	−28	−22
July . .	+34	+49	− 4	+37	− 6	+58	+21	+52	+40	+48
August . .	+ 2	+ 1	+47	+ 9	+30	−15	0	−17	− 1	+13
Summer . .	+42	+28	− 2	+40	−27	+17	−24	+12	+11	+39
					AUTUMN 1898.					
					Temperature.					
	°	°	°	°	°	°	°	°	°	°
September .	+3·3	+4·3	+4·5	+3·8	+4·0	+3·0	+4·3	+3·3	+3·8	+3·5
October . .	+4·3	+3·5	+4·8	+4·0	+4·8	+3·5	+3·3	+4·0	+4·5	+3·5
November .	+2·6	+1·8	+3·4	+2·8	+3·2	+2·4	+1·8	+1·6	+3·0	+1·2
Autumn . .	+3·4	+3·2	+4·2	+3·5	+4·0	+3·0	+3·1	+3·0	+3·8	+2·7
					Rain.					
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
September .	−2·1	+0·1	−1·5	−1·9	−2·1	−2·0	+0·3	−0·6	−1·9	−0·8
October . .	+1·7	+1·2	−0·2	+0·6	−0·2	−0·3	−0·6	−1·3	+1·0	+0·9
November .	−0·4	+0·9	0·0	−0·8	−0·6	−0·4	+0·7	+0·9	+0·3	+1·1
Autumn . .	−0·8	+2·2	−1·7	−2·1	−2·9	−2·7	+0·4	−1·0	−0·6	+1·2
					Sunshine.					
	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.
September .	+38	+33	+52	+49	+54	+11	+28	−20	+ 1	+12
October . .	−36	− 3	−41	−42	−27	−16	− 8	−20	−18	− 8
November .	− 1	− 6	+ 6	−10	+11	+ 3	−19	−14	−14	−13
Autumn . .	+ 1	+24	+17	− 3	+38	− 2	+ 1	−63	−31	− 9

The above Table has been compiled from the variations from the mean given i *Weekly Weather Reports* issued by the Meteorological Office.

Tacolneston (E)—11th. Wryneck first heard. 27th. House-martin first seen. *Peterborough* (E)—10th. Peas sown on February 28th, only now above ground. *Palé* (F)—A very fine show of blackthorn bloom. *Conway* (F)—13th. Corncrake first heard. *Ambleside* (F)—20th. Corncrake first heard. *Piperstown* (G)—15th. Corncrake first heard. *Edgeworthstown* (G)—10th. Chiffchaff first heard. *Westport* (G)—13th. Martin first seen. 20th. Corncrake first heard. *New Galloway* (H)—3rd. Grey wagtail first seen.

MAY.—*Marazion* (A)—5th. Swift first seen. 31st. Butterflies very scarce, only 2 specimens noticed as yet. *Altarnon* (A)—1st. Corncrake heard. *Bridgend* (A)—Ladybirds very numerous this spring. *Aberystwith* (A)—Not a single wasp seen during the spring. *Killarney* (B)—Again very few wasps this spring. *Ferns* (B)—16th. Potatoes, beans, and young laurel shoots blackened by last night's frost. *Glendalough* (B)—Hollies and hawthorns flowered profusely. *Geashill* (B)—1st. Landrail heard. *Bembridge* (C)—13th. Potatoes, etc., cut by frost. *Buckhorn Weston* (C)—Slugs numerous. Both vegetable and flower seeds came up badly. *Chislehurst* (C)—Horse-chestnuts and hawthorns flowering abundantly this year. 6th. House-martin first seen. 25th. Swift first seen. *Churt* (C)—Plums, pears, and cherries have suffered severely, owing to frost, in exposed places. *Chiddingfold* (C)—Until the middle of the month, the oaks appeared to have escaped the blight which attacked them the last 2 years, but after this the caterpillars increased rapidly and inflicted great damage. *Marlborough* (C)—Asparagus and peas made remarkably slow growth; while grasses, on the other hand, made very strong growth. *Cheltenham* (D)—Abundant blossom on pears, apples, horse-chestnut, hawthorn, etc. Great plague of aphis on roses, etc. Slugs and snails very numerous. *St. Albans* (D)—2nd. Swift first seen. *Lexden* (E)—15th. Swift first seen. *Palé* (F)—The wild cherry, crab-apple, horse-chestnut, and hawthorn were in great beauty during the month. *Piperstown* (G)—Very little bloom on the hawthorn this year. *Westport* (G)—5th. Swift first seen. *New Galloway* (H)—17th. Swift first seen. *Thirsk* (I)—20th. Autumn-sown wheat almost 1 foot high. *Corbridge-on-Tyne* (I)—1st. Corncrake first heard. 7th. Swift first seen. *Chirnside* (I)—6th. Corncrake first heard. 14th. Swift first seen. *Newmill* (J)—Abundant blossom on apples, cherries, and forest trees. 16th. Swift first seen. 18th. Corncrake first heard. *Dingwall* (K)—Queen wasps very numerous this year. *Watten* (K)—An unusually profuse display of blossom on apple trees, gooseberries, and currants.

JUNE—*Mawnan* (A)—16th. Hay-cutting began. *Altarnon* (A)—3rd. Few insects as yet. No St. Mark's Fly, and few ladybirds or butterflies. *Castleton* (A)—Few butterflies were seen during the first half of the year. *Bridgend* (A)—Hardly any wasps seen during the year. 11th. Hay first cut. Slugs numerous during the early summer. *St. Arvans* (A)—5th. Much aphis on roses and fruit trees. *Glendalough* (B)—All garden seeds have germinated badly. Slugs very destructive during this month and in May owing to constant wet. *Buckhorn Weston* (C)—Very few butterflies. *Coneyhurst* (C)—Very few wasps, but blue-bottle flies very numerous. 29th. Cuckoo last heard. *Churt Vicarage* (C)—5th. First swarm of bees. Very few butterflies. *Churt* (C)—Butterflies scarce. *St. Albans* (D)—Dog-rose unusually full of bloom. *Berkhamsted* (D)—Great plague of greenfly amongst roses. *Harpenden* (D)—14th. First wheat ear seen out of its sheath. Much aphis early in June, especially on roses, plums, pears, and currants. There is also much rust in the wheat crops, particularly on the lighter soils. *Beeston* (D)—Pears dropping off in quantities. *Tacolneston* (E)—Apple trees, which looked healthy and likely to bear well up to June, are blighted and look as if a flame had scorched them. Wild roses especially abundant and beautiful. *Brunstead* (E)—Comparatively few martins or swallows this season. *Altnafoyle* (G)—A feature of the season has been the profusion of

bloom on the wild dog-rose. *Thirsk* (I)—12th. A field of clover cut for hay. *Newmill* (J)—Butterflies and wasps scarce.

JULY.—*Mawnan* (A)—8th. Hay harvest just over. 30th. Corn harvest began. Corn taller than for many years. *Long Ashton* (A)—Fruit trees much blighted. *St. Arvans* (A)—An unusual number of snails in the garden. Meadow brown butterflies numerous. 23rd. First corn cut. *Geashill* (B)—6th. Potato blight first observed. Weeds very abundant and vigorous. *Chislehurst* (C)—17th. Many leaves have already fallen from the Spanish chestnuts. *Churt* (C)—6th. Cuckoo last heard. *Beckford* (D)—2nd. Cuckoo last heard. *St. Albans* (D)—Nearly all our currants ruined by aphis. *Ullenhall* (D)—Many large white butterflies this summer, but very few brown ones. *Lexden* (E)—Butterflies have been scarce. *Palé* (F)—Wild roses very full of flower.

AUGUST.—*Mawnan* (A)—24th. Some blackberries already ripe. *Altarnon* (A)—17th and 18th. Severe thunderstorm with large hailstones. *St. Arvans* (A)—Wasps numerous. *Bembridge* (C)—Vegetables very scarce. *Havant* (C)—Privet hawkmoth caterpillars very plentiful. *Chislehurst* (C)—Leaves and fruit falling from the apple trees. 25th. Red Admiral butterfly seen. *Coneyhurst* (C)—31st. Owing to drought, birches are losing their leaves very fast, some being already nearly bare. *Churt* (C)—The heather was never more beautiful. Hazel nuts plentiful and good. *East Molesey* (C)—1st. Limes losing their leaves. Very few wasps. *Marlborough* (C)—An exceptionally bad season for all kinds of cabbage, which were smothered with aphis and eaten up by caterpillars of the large and small white butterfly. From about 70 plants of broccoli and Brussels sprouts I collected 2400 larvæ of these 2 species, principally the former. *Cheltenham* (D)—Wasps very numerous. *Harpenden* (D)—Wasps comparatively scarce. *Farnborough* (D)—Wasps excessively abundant. *Ripley* (D)—The best summer for farmers for many years, the worst for gardeners. *Antrim* (G)—4th. First wasp seen. Wasps very scarce this year. *Chirnside* (I)—20th. Swift last seen. *Newmill* (J)—22nd. Swift last seen.

SEPTEMBER.—*Altarnon* (A)—Caterpillars of large white butterfly did much damage to cabbage and other garden crops. *St. Arvans* (A)—No sloes this year. *Killarney* (B)—A plague of wasps. *Geashill* (B)—There are but few earwigs. Numerous caterpillars on cabbage. *Bembridge* (C)—Blackbirds, being short of water and moist foods, are attacking the apples. *Buckhorn Weston* (C)—Quite a plague of caterpillars. *Havant* (C)—Plague of the large white butterfly caterpillars, which did great damage to all kinds of cabbages. *Churt Vicarage* (C)—24th. Grass fields quite brown. Apples falling rapidly. *Oxford* (D)—Some trees (copper beech, limes, birch, and elms) bare of leaves early in the month, owing to drought, whereas other trees held their leaves till the beginning of December, due to absence of sharp frosts and strong winds. *Watford* (D)—3rd. No grass for the cows in my meadow. *Hodsock* (D)—Wasps are very numerous. *Brunstead* (E)—Leaves of many deciduous trees falling prematurely, owing to drought. Wasps more numerous than I remember during the 11 years I have been here. *Cronkbourne* (F)—A remarkable absence of wasps. *Orry's Dale* (F)—Great absence of wasps and butterflies. *Piperstown* (G)—Wasps a plague this year. *Antrim* (G)—2nd. The leaves of apple trees began to fall in July, and now some trees in my garden have lost nearly two-thirds of their foliage. *Altnafoyle* (G)—Very few wasps this year. *Duror* (H)—A plague of wasps. *Thirsk* (I)—18th. Harvest generally over. The shortest harvest on record. *Durham* (I)—Insects, probably owing to the summer drought, came out most intermittingly, and lasted much longer in consequence. *Lilliesleaf* (I)—Large swarms of wasps. *Littleton*—Wasps more numerous than for many years. *Newmill* (J)—Wasps numerous. One of the shortest harvests on record.

OCTOBER.—*Marazion* (A)—Swifts more numerous than swallows this year.

Kingfishers unusually numerous all through the autumn. *Altarnon* (A)—An autumn of great beauty, as the foliage of trees was so rich and lasting in colour. *Havant* (C)—Mushrooms very plentiful at the end of the month and during November. *Churt Vicarage* (C)—31st. The last of five dishes of mushrooms gathered in my meadow since the rain. An abundant crop of blackberries this year. *East Molesey* (C)—14th. Grass until after this date remained brown. *Cheltenham* (D)—Apples and pears ripened very quickly, and the former have not kept well. *Watford* (D)—1st. Apples a good crop, but small in size, also potatoes. *Beeston* (D)—20th. A large crop of mushrooms. *Hodsock* (D)—Garden very gay with flowers. *Lexden* (E)—27th. Last martin seen. *Clenchwarton* (E)—27th. Jerusalem artichokes very tall and in full flower. *Ardgillan* (G)—13th-19th. A continuous gale from the sea, which had a severe effect on all trees still in green leaf for a considerable distance inland. *Jardington* (H)—14th. Wild roses still in bloom in the hedges. *Duror* (H)—An unusually fine crop of blackberries. *Lilliesleaf* (I)—The trees kept their leaves till the very end of the month, and then they fell without changing colour. *Aberdeen* (J)—4th. The finest autumn bloom on roses for many years. Flower-beds as bright as they generally are in August.

NOVEMBER.—*Altarnon* (A)—30th. Elms still in full leaf. *Sidcot* (A)—23rd. Dahlias killed by frost. *St. Arvans* (A)—13th. Elm foliage still green. 22nd. Dahlias killed. *Killarney* (B)—21st. Heliotrope still in flower. *Glendalough* (B)—Roses, etc., still in flower at end of month. *Geashill* (B)—30th. Wasps in number on the ivy blossoms. *Bembridge* (C)—Many trees that had rested through the hot weather are coming into leaf and flower again. 22nd. Dahlias killed by frost. *Havant* (C)—Deciduous trees, even the larch, retained their leaves at end of month. *Churt Vicarage* (C)—14th. Dahlias killed by frost. *Chiddingfold* (C)—Autumn tints still fine right up to the end of the month. 22nd. Dahlias killed. *East Molesey* (C)—20th. Most of the leaves are still on the trees, and some trees quite green. 30th. An elm tree still quite green. *Beckford* (D)—23rd. Dahlias killed by frost. *Watford* (D)—11th. Garden gay with flowers. 23rd. Heliotrope killed. *Berkhamsted* (D)—23rd. Dahlias killed by frost, 3 weeks later than the average date of their destruction in the previous 13 years, and with one exception (1894) later than in any of those years. *Ullenhall* (D)—18th. Strawberries in bloom. *Beeston* (D)—12th. Tea-roses, dahlias, Japanese anemones, etc., still in flower. *Hodsock* (D)—The leaves of trees fell very late. 22nd. Dahlias cut by frost. *Macclesfield* (D)—Many trees retained their foliage until nearly the end of the month. *Lexden* (E)—Leaves have stayed long on most trees. *Brunstead* (E)—17th. Good mushrooms to be gathered in the fields until now. *Ambleside* (F)—50 different wild flowers were found during the month. *Antrim* (G)—20th. Until last night's frost, penstemons, verbenas, dahlias, fuchsias, and roses have remained fresh and continued to bloom. *Ballynagard* (G)—Towards the end of the month an apple tree in my garden had blossoms on it. *Ramelton* (G)—Flowering plants continued in blossom much longer than usual this autumn. *Duror* (H)—26th. Dahlias, roses, etc., remained in blossom until to-day. *Durham* (I)—15th. Red campion in fairly full bloom. *Newmill* (J)—12th. A small second crop of raspberries. *Roshven* (K)—22nd. Dahlias killed by frost. Trees shed their foliage remarkably late, indeed on the 30th there were still green leaves on some deciduous trees.

DISCUSSION.

The President (Mr. F. C. BAYARD) said the thanks of the Society were due to Mr. Mawley for his Report. He (the President) had been under the impression

that 1898 was much earlier, from a phenological point of view, than was proved by Mr. Mawley's figures and diagrams. He was pleased to see the statement referring to insects in a diagrammatic form for the first time. He thought insects were a great feature, phenologically speaking.

Mr. B. LATHAM said there was no doubt that last year was one of exceptional drought; that one of the remarkable things that struck him with reference to this period of drought was that, in all the early spring months of the year, the evaporation was very much under the average, especially in May, June, and part of July. This perhaps accounted for the luxuriant vegetation in the early part of the year. At his own house at Croydon, although no water had been used for watering purposes, it was not until after the middle of July that the lawns began to burn up; but up to that period they had been in a greener condition than in previous years when they had been regularly watered. There was also another peculiarity with regard to the season, and that was that in most of the chalk wells the waters fell continuously from the spring of 1897, without any perceptible rise in the spring of 1898, and did not begin to rise until the latter part of November 1898.

Mr. G. J. SYMONS regretted that he could not speak with certainty as to the amount of evaporation during years of drought; but with regard to the state of Mr. Latham's lawn, he (Mr. Symons) thought it was much more fortunate than most others. In many places there was evidence of grass having suffered severely from the prolonged drought, his own little plot of grass included, which he had never known in such a bad state from this cause since the year 1868, when it was probably worse. At the end of September last he had occasion to go from London through Folkestone to Paris, and was much struck by the parched state of the country, which was a uniform brown, so that it was difficult to distinguish corn-stubble from pastures. The green was limited to where brooks and streams had wrought their influence and percolated the soil to perhaps 100 feet of either bank, but generally the country seemed browned to such an extent that he personally had never seen in the south-east of England before. The same features existed in northern France, and there was very little green to be seen until some miles beyond Amiens.

Dr. C. T. WILLIAMS said he did not mean to attempt to discuss the Report, but to add his experience of the effects of the drought of last year at his residence in Surrey. This was in an elevated position, on a sandy soil, the latter feature probably making the drought more severely felt. The lawn bore a strong resemblance to the front door mat; and shrubs, rhododendrons, etc. (which it was impossible to supply with water, by reason of its scarcity), suffered severely, many seemingly dying off as when killed by frost, and it was remarkable how many, on the return of rain, had regained their vitality. His was not an isolated case, as his neighbours had suffered in the same way. The dearth of water also seriously inconvenienced the residents in the neighbourhood, and some had left their houses for the time in consequence.

Mr. J. E. CLARK said that towards the end of September he took a cycle run in the south-east of England to see the state of the country, travelling from Croydon through Kingston and Haslemere towards Chichester, and back by Horsham and Crawley, and the conclusion he had come to was, that the effects of the drought could only be compared in severity to that experienced in the west of England in 1868. Young trees in plantations seemed to be dead. He had never heard of so widespread destruction of trees by drought before. Comparing the winters 1897-98 and 1898-99, it was remarkable that the latter, though the milder, could not boast so many plants in flower as the former winter. On a visit to Street, Somersetshire, for Christmas week 1897, he had counted 138 garden flowers and 48 wild flowers in blossom. At the same place at Christmas 1898 he had only found 76 garden flowers in bloom, while the

wild flowers also (32) were in less profusion. Primrose, dog mercury, and hazel were very scarce in woods where they are frequently common at Christmas. At the Soirée of the Croydon Microscopical Society held in November, a basket of garden flowers is usually exhibited and a list of wild flowers. This year the latter reached 107, which he (Mr. Clark) thought would have been considerably augmented had the weather been more favourable to their late duration. It was remarkable that the apple crop of last season was keeping so badly.

Mr. F. J. Brodie remarked that he could confirm the statements made by previous speakers as to the state of the pastures. In the autumn of last year he had occasion to travel up to Cumberland. After leaving the dry parched south he had evidently gone to sleep in the train, and, when he awoke, he found the country fresh and green, which was accounted for by the fact that in the more northern part of the country the rainfall was not much less than the average. And it was often the case that when a drought was experienced in the south of England, that the north had an excess of rainfall. He was sure that he did not know how those people who were favourable to the theory of the moon's or other planetary influence on rainfall would explain this difference in an area so limited as the British Isles.

Mr. C. Harding thought that Mr. Mawley's comparisons of the different districts were very interesting and valuable. He (Mr. Harding) had thrown the Greenwich rainfall together for half-yearly periods, October to March and April to September, from 1841 to last year, and it might interest Fellows to know that the record for the twelve months ending September last was lower than that for any corresponding period.

Mr. E. Mawley, in reply, said, with reference to Dr. Williams' remarks on the recuperative powers of vegetation, that it was truly surprising how very rapidly the grass in the pastures and on the lawns had regained its green appearance last autumn under the influence of the October rains. It was difficult to understand why vegetation generally was not at the present time more forward, instead of being less forward, than in February last year. For the ground temperatures during the past three months had been, as a rule, higher than in the same three months in 1897-98, the subsoil moister, and there had been a better record of sunshine. He thought the explanation of apples keeping so badly in some districts was that they had ripened so very quickly, instead of becoming gradually matured. He was interested to learn from Mr. Clark that the exhibition of flowers gathered on the date of the Croydon Microscopical Soirée in November, which he (Mr. Mawley) had started twenty years ago, was still maintained. In order that the records might be rendered fairly comparable, it was important that the flowers should, as far as practicable, be obtained from the same gardens year after year. Mr. Harding's plan of dividing the year, as regards rainfall, into two distinct and equal periods, was, he considered, a very sensible one, as the winter rains more especially affected the underground water supply, whereas those which fell between March and October alone, as a rule, affected vegetable life generally. The past two years he had gathered in his garden the last rose of the season as late as Christmas eve, but this was rather due to the number and variety of the rose plants he grew than to the local climate, which was cold and backward.

THE CIRCULATION OF THE ATMOSPHERE.

BY PROFESSOR WILLIAM MORRIS DAVIS,
HARVARD UNIVERSITY, U.S.A.

[Read February 15, 1899.]

THE circulation of the atmosphere is one of the earliest and one of the latest problems of meteorology. It is referred to as of prime importance in elementary study, where it receives a general solution when explained as depending upon differences of temperature between equator and poles. It is encountered as the most difficult chapter of advanced study, where its final solution is not yet reached, so many are the complications that arise between general cause and detailed effect. In spite of the importance of the subject, its treatment is ordinarily inadequate, inasmuch as the serious student seldom gains from the text-books in current use a comprehensive view of the great problem. To illustrate this criticism on prevailing methods, let us for a moment place ourselves in the position of beginners, and advance through successive stages in the discussion of the circulation of the atmosphere to a grade that may be called collegiate, leaving the higher reaches of the problem to those who can treat it mathematically.

The young scholar learns, by local observation, that the air is generally in motion, and that a count of his records of its movement for a month or more shows the winds from certain directions to be more frequent than from others. If his attention is next directed to the drift of the lower clouds, their motion will usually be found to agree with that of the prevalent surface winds. Local records may then be supplemented by teacher, text-book, or atlas, and thus the pupil learns that the winds in all parts of the world are as well-ordered in their courses as at home, that winds of neighbouring regions usually have accordant directions, that winds over the oceans are much more regular than upon the lands, and that when considered broadly the general system of prevalent winds is relatively simple over much of the world. The latter statement is best warranted if attention is given chiefly to the winds of the Southern Hemisphere, where the continents occupy a small part of the total area: it finds much less support when the winds of the lands are examined. Hence, for the present, the latter class of winds will not be considered. In brief, two halves of the torrid zone are occupied by the oblique Trade Winds,[1] and the temperate zones by the

[1] There appears to be a prevailing misconception as to the derivation of the term Trade Winds. For example, Buchan writes in his *Handy Book*, p. 214: "From the great service these winds render to navigation on account of their steadiness and constancy, they are called the *Trade-Winds.*" Again, in *Physiography for Beginners*, by A. T. Simmons (Macmillan, 1898), it is stated on p. 230 that the Trade Winds "were so called because of the assistance they rendered to the navigation of trading vessels before the introduction of steamers." Dictionaries usually give a similar explanation of the term, but Skeat, in his *Etymological Dictionary*, says: "Trade-wind, a wind blowing in a constant direction, formed from the phrase 'to blow trade,' to blow always in the same course." The first use of the term seems to have been by Hakluyt, who wrote in 1600: "The wind blowing trade, without an inch of sail, we spooned before the sea" (*Voyages*, iii. 849). A century later, Dampier wrote: "Trade winds are such as do blow constantly from one point or quarter of the compass" ("Discourse of the Trade Winds," in his *Voyages and Descriptions*, London,

prevailing Westerlies; the four wind belts thus defined being divided by belts of light, baffling breezes, with more or less frequent calms.

On reaching this stage of the study, it is natural that some explanation of the movement of the winds should be asked for and given. The pupil then learns that the surface winds are the lower members of a general circulation that is produced by the difference of temperature between the equator and the poles, by which the equilibrium that would prevail in an atmosphere of uniform temperature is disturbed. The circulation must be as persistent as the difference of temperature. If the teacher has a fondness for generalisation, it might be added that such a circulation may be confidently expected to occur on any planet that has an atmosphere and that is warmed around its equator by a hot sun: hence it may be called the *planetary circulation*.

Let us now consider the case of an exceptional boy who has an investigating turn of mind and who tries to think for himself. Recalling what he has learned in physics of the convectional circulation of gases, he reasons that if the atmospheric circulation is due to differences of temperature, then high pressure should prevail at sea-level in the cold polar regions, and low pressure in the warm equatorial regions, and the surface winds should move prevailingly from poles to equator, while a compensating current returns from equator to poles aloft. With these deductive conclusions in mind, the exceptional boy says to himself: "Now I can tell whether that explanation of the winds is right or not; if right, the theoretical distribution of surface pressures and the expected course of the surface winds must agree with the facts of observation." (Alas! that this exceptional boy is so largely a creature of the imagination; but as long as success in teaching is measured by quantity of fact instead of by quality of intelligence, and as long as the inculcation of scientific method by example is replaced by an obedient lesson-learning of ready-made results, the boy must be unknown to most of us.)

A brief review of the wind charts and an examination of the pressure charts, now seen for the first time, suffice to show that the facts contradict the expectations of theory; and the pupil goes to the teacher saying that he finds it difficult to believe that the convectional explanation of the winds is correct. The teacher may then perhaps reply: "I do not wonder that you are not satisfied with the theory, as you have applied it, for you have omitted a very important element of the problem. You have considered only a non-rotating earth. On the actual rotating earth the currents of the atmosphere are turned from their north and south courses, and thus the oblique directions of the winds are accounted for." "I should like to know more about that," says the boy, "and also about the distribution of pressure. It is not high in the polar regions, as one would expect; the pressure is comparatively low there, and it is higher around the tropics. What does that mean?" . . .

It is not worth while to carry the parable further, for it would be difficult to imagine what the teacher would say in answer to the last

1705, vol. ii. pt. iii. p. 1). Hadley, in his essay "Concerning the Cause of the General Trade Winds," included the Westerly winds of middle latitudes as well as those winds of the torrid zone to which the term "Trade Winds" is now restricted; he used the phrase, "West Trade Winds without the Tropicks" (*Phil. Trans.* xxxix. 1735). See the *American Meteorological Journal*, iii. 1886, p. 111.

question; so little general acquaintance is there with the principle that underlies the distribution of atmospheric pressures. Let us, therefore, look into the historical development of the subject to see if it reaches a satisfactory solution of the difficulty, bearing in mind that the special object of our search is a reconciliation between the generalised facts of observation and the reasonable consequences of the theory by which it is generally agreed that the facts are to be explained. The oblique courses of the winds will be considered first, and then the peculiar distribution of pressures.

Halley's suggestion that the oblique course of the Trade Winds resulted from their tendency to follow the area of highest temperature —which moves westward after the sun—was supplanted in 1735 by Hadley's explanation of the effect of the earth's rotation, which he applied to the prevailing Westerlies as well as to the Trades. Forgotten for many years, and independently reached by several later writers, when Hadley's priority was not recognised, this explanation has seemed so sufficient that it is still widely quoted, although it has been repeatedly shown to be seriously incomplete. The implication that the earth's rotation can affect only the north or south component of motion is well known to be wrong. Whatever the direction of motion, the deflective force is the same; it varies only with the velocity of the motion and with the sine of the latitude in which it takes place. Those who wish to trace the development of this expansion of Hadley's views will find some interesting articles referred to in the *American Meteorological Journal*, vol. x. p. 195 (1893).

Much more serious is the omission from Hadley's statement, and from that of those who adopt it, of all consideration of the effect produced on the distribution of pressure by the deflection of the winds from their meridional courses and by the associated changes in their velocities. So long as these important elements are omitted from the problem, the serious student would be well warranted in objecting to the sufficiency of the convectional theory of atmospheric circulation. If he makes no objection, it must be that he is too accustomed to basing his opinions on authority instead of on evidence. It is utterly unscientific to believe in a theory whose deduced consequences are not borne out by facts; yet what is more common than to find among students of meteorology an acceptance of the convectional origin of the general circulation of the atmosphere in face of the (to them) unexplained occurrence of relatively low pressure in the polar regions! They should rebel against a theory that is so incapable of bearing a reasonable test. If assured that the theory is correct, they should rebel against the insufficiency of the evidence that is presented to them in its favour. Some years ago, before the distribution of atmospheric pressure was well known, no such rebellion could have been expected; but to-day, when nearly all text-books present the results of Buchan's invaluable studies on this subject, it is curious that students who are familiar only with Hadley's explanation of the effect of the earth's rotation should continue to believe in the convectional theory of the winds.

The difficulty in which the theory is ordinarily allowed to remain is recognised but not explained in Scott's *Elementary Meteorology* (1887). In that well-known book, the author shows that the difference of

temperature between equator and poles causes low pressure around the equator and greater pressure in higher latitudes (p. 238); but it is afterwards added that "there are, however, two great facts, as to the distribution of pressure and atmospheric circulation, . . . of which a satisfactory interpretation has not yet been given. I speak of the exceptionally low barometer readings near the South Pole and of the strong Westerly winds of the Southern Hemisphere" (pp. 250, 251). The student is thus left in a dilemma: he might fairly say that the convectional origin of the general atmospheric circulation is not established, inasmuch as no satisfactory explanation is here given for the striking discrepancy between theory and observation in the far southern regions.

Buchan's *Handy Book* (1868) takes a different course, in attributing a great importance to water vapour. "All winds are directly caused by differences of atmospheric pressure. . . . Differences of atmospheric pressure, and consequently all winds, arise from changes occurring either in the temperature or the humidity of the air" (p. 212). The air tends to move towards regions of greater moisture, and "it is in this way that all the more violent commotions of the atmosphere—gales, storms, tempests, and hurricanes—originate" (p. 213). Most remarkable "is the region of low pressure surrounding the South Pole" (p. 54). "The influence of high temperatures in lowering the mean annual pressure over any portion of the earth's surface is slight in comparison with the depressing influence of the vapour in the atmosphere. . . . It may therefore be concluded that *the chief disturbing influences at work in the atmosphere are the forces called into play by its aqueous vapour*" (p. 55). Twenty years later, in the famous "Challenger" *Report on Atmospheric Circulation* (1889), Buchan wrote: "The Arctic and Antarctic zones of low pressure, and the equatorial belt of low pressure generally, are all but wholly occasioned by a comparatively large amount of vapour in the atmosphere" (p. 73); but "the temperature also plays no inconspicuous part directly in destroying the equilibrium of the atmosphere" (p. 74). No physical argument or quantitative calculation is adduced in support of this conclusion, and in view of the well-known greater value of absolute humidity in the warm air of the torrid zone than in the cold air of high latitudes, it would seem more reasonable to conclude that the low Antarctic pressure is in spite of, not on account of, the unequal distribution of vapour in the atmosphere. Ferrel gives us definite grounds for this opinion. He calculates that the average effect of water vapour is the same as if the air were dry, but were given an increase of 2°·7 C. in temperature around the equator. "Upon the whole, therefore, considering the whole depth of the atmosphere, the effect of the aqueous vapour is small, but even this depends indirectly upon difference of temperature" (*Popular Treatise on the Winds*, 1889, pp. 101, 102).

The only effective explanation that the believer in the convectional circulation of the atmosphere can give for the unexpectedly low pressure of the cold polar regions, and of the equally unlooked-for high pressure belts around the meteorological tropics, is found in the centrifugal forces exerted by the general winds. This is an eminently competent explanation, but it is very generally overlooked. It is curious that a generation familiar with the polar flattening of the earth on account of the centrifugal force of its rotation, should not take more kindly to the still greater flattening

of the faster-rotating atmosphere of middle and higher latitudes. This is truly a crude way of expressing the matter, but it contains the essential truth; and if anything is said about the distribution of pressure in very elementary teaching, a brief statement of this kind may suffice. The historical development of the subject may be found in the Bakerian Lecture by Prof. James Thomson, laid before the Royal Society, March 10, 1892, shortly before his death (*Phil. Trans.* vol. clxxxiii. p. 653); and there the matter might well rest, were it not that a serious misunderstanding of it still exists, as is indicated in a conference regarding the "Scientific Advantages of an Antarctic Expedition" last winter, of which a report is published in the *Proceedings of the Royal Society* (lxii., 1898), and again in the *Scottish Geographical Magazine* for October 1898. The misunderstanding that I refer to concerns the theory of the winds as explained by Prof. William Ferrel; and as it is partly my fault that he was misunderstood, I desire to place his real opinions before British meteorologists, in so far as they touch Antarctic winds and pressures, and as they can be very briefly stated.

Ferrel was a school teacher, self-taught, with a genius for mathematics. On reading the fantastic theory of the winds given in Maury's *Physical Geography of the Sea*, he felt strong dissent from it, and at the request of a friend he wrote out his own views, which were published—one might better say immured—in the Nashville (Tenn.) *Journal of Medicine and Surgery* for 1856.[1] Here he explained how the winds, deflected to oblique courses by the earth's rotation, would reduce the atmospheric pressure in the polar regions from the high value it would otherwise have. At the same time, he used the observations of Ross and Wilkes in far southern latitudes to show the occurrence there of South-east or Polar winds, and gave them a definite place in his system of atmospheric circulation.

The wind system, as thus represented, was in the next year distinctly and independently improved upon by James Thomson, as is shown in an article "On the Grand Currents of the Atmospheric Circulation" (*Brit. Assoc. Rep.*, 1857, pp. 38, 39); for although Thomson did not recognise the outflowing Polar surface winds, his scheme for the prevailing Westerly winds of temperate latitudes is essentially the one to-day in favour with mathematical meteorologists. It may seem surprising to some that I should give preference to a scheme in which fairly well-established facts (the Polar surface winds) are omitted, and a theoretical matter (the three wind strata of temperate latitudes) is introduced; but inasmuch as a scheme of this kind is an effort to give a general representation of all pertinent facts, it seems to me clear that the scheme in which the best generalisation is reached is the superior one. Indeed, had Thomson pursued meteorological studies as actively as Ferrel did during the thirty years after the date of his first essay, meteorologists might have owed as much to the Irish as to the American investigator. As far as I know, the Bakerian Lecture of 1892 (*Phil. Trans.*, 1892, pp. 653-684) was Thomson's next publication on the subject. He there gives an interesting account of the history of atmospheric circulation,[2] but his scheme of

[1] A reprint of this article may be found in *Professional Papers, U.S. Signal Service*, No. viii., 1882.

[2] Reference is there made to an article by J. J. Murphy, on the "Circulation of the

the general winds again omits the Polar surface outflow. This, however, should not be held to militate seriously against his theory, which may be very easily modified so as to remedy the omission.

Returning to Ferrel, it is interesting to see how persistently the outflowing Polar winds appear in his successive essays down to the latest of the series. He repeatedly shows that, in the case of no friction, there could be no air at the poles on account of the enormous centrifugal force of the unretarded circumpolar whirl; but that, as there must be some friction, there will only be a reduction of polar pressure somewhat below the value due to differences of temperature alone; and that, as land masses are more extensive in northern than in southern latitudes, the deficiency of pressure will be less marked around the North Pole than around the South Pole. Yet even around the South Pole, a residual high-pressure area with centrifugal surface gradients is implied, for reference to outflowing Polar winds, as observed by explorers in high latitudes, is constantly made. The mathematical essay on "The Motions of Fluids and Solids relative to the Earth's Surface" (*Math. Monthly*, i. ii., 1859, 1860; reprinted in pamphlet form, New York, 1860) made a great advance on the popular article in the *Nashville Journal*. The mathematical treatment has been described as crude, but it seems to me that this is excusable in the work of a self-taught mathematician, who, in spite of his more cumbersome methods, nevertheless gave reasonable explanation to various facts concerning the atmosphere which had in earlier years been seriously misunderstood. Here the circumpolar movement of the general winds in temperate and higher latitudes is, again, stated to be the cause of the relatively low pressure in the polar regions, and of the belts of high pressure that lie near latitudes 30° N. and S.; but the original scheme of wind movements is modified so as to bring in the three wind strata in middle latitudes. How far this was original, how far an adoption of Thomson's scheme, I cannot say; but it is interesting to see that the Polar winds, absent in Thomson's scheme, are still retained in Ferrel's.

An outline of the results of the above-named essay is given in the *American Journal of Science* for 1861 (2 Ser. xxxi. pp. 27-51), and, as before, the North-east Arctic winds and the South-east Antarctic winds are represented as deduced from theory and confirmed by observation. In a brief article on "The Cause of the Low Barometer in the Polar Regions," which was printed in *Nature* in 1871 (iv. p. 226), objection was made to the sufficiency of Buchan's explanation by excess of vapour, and the general circumpolar movement of the winds was advocated instead. "Recent Advances of Meteorology" (*Report of the Chief Signal Officer*, 1885) and the *Popular Treatise on the Winds* (1889) contain abundant indication of the recognition of Polar winds as a characteristic part of Ferrel's theory. It is only in the "Meteorological Researches for the Use of the Coast Pilot" (*U.S. Coast Survey Report* for 1875 (1878), pp. 369-412) that the Polar winds are omitted from the schematic diagram, and this is evidently because the diagram (Chart VII.) was explicitly drawn to represent the theoretical case of a homogeneous surface of the earth; that is, of an even earth, on which there would be little friction to retard the general circumpolar component of the circulation.

Atmosphere" (*Belfast N. H. and Phil. Soc.*, 1856), in which centrifugal force is given as the cause of low pressure in high latitudes.

Now in view of this consistent series of statements by Ferrel, it is a matter of regret to find his theory condemned as inconsistent with facts and incapable of explaining the winds of the Antarctic regions. For example, Dr. Buchan says: "Some years ago, a theory of atmospheric circulation was published by the late Prof. Ferrel, which, as it is not accordant with the broad results arrived at in the Report on Atmospheric Circulation in the *Challenger Reports*, calls for serious consideration on account of its bearing on any attempt proposed to be undertaken for the exploration of the Antarctic regions" (*Proc. Roy. Soc.*, lxii., 1898, 443). But instead of quoting Ferrel, Buchan quotes a phrase from an elementary text-book in which it unfortunately happens that no sufficient justice was done either to the Polar winds of the Antarctic regions or to Ferrel's early and continuous recognition of their occurrence and their meaning. Buchan then concludes that "both the surface winds and the upper aerial currents are diametrically opposed to the requirements of this [Ferrel's] theory" (*l.c.* 446). If the absence of Antarctic Polar winds from a theoretical statement condemns the theory, it is evidently Thomson's theory that suffers, not Ferrel's; but the presence or absence of such winds is so easily accounted for under these theories by assuming greater or less values of resistances, that either theory readily adapts itself to the special case pointed out by the facts. He must indeed be a carping critic who would seriously lessen the value of Thomson's theory merely because its very simple and general statement did not include the special case of Polar winds. The great irregularity of the wind system in the northern hemisphere clearly indicates a departure from a simpler system on account of the disturbances introduced by the lands; thus it is made extremely probable that if there were no land at all in the Southern Hemisphere, even the Antarctic Polar winds would disappear, and the Westerlies would unite in a continuous whirl around the pole. It would seem as if Thomson's phrase "Grand Currents" was intended to apply to some such ideal case, for he did not concern himself with Monsoons or other effects of land disturbances. Likewise, Hadley's explanation of the "General Trade Winds" took no account of the eddying of the prevailing winds around great anticyclonic areas that occupy oceanic centres during the summer; yet no one could justly complain of such an omission, for the eddies are evidently only matters of secondary importance in the problem that Hadley was discussing.

It is, however, true that a navigator who knew nothing of theoretical meteorology and who cared only to reach port as quickly as possible might disregard a book in which specific sailing directions were replaced by schemes and discussions concerning the general circulation of the atmosphere. In the same way, he would object to a manual that gave a general explanation of planetary motions, instead of a rule of thumb, by which his latitude could be determined. On the other hand, the student who wishes to gain a broad view of the physics of the earth would set aside a statistical account of the winds in this and that part of the world for a broad discussion of the general movements of the atmosphere; he would prefer an explanation of fundamental principles to a table of empirical statements. When it comes to neither the navigator nor the student, but to the scientific investigator, the course he will pursue is largely determined by his temperament. Thus, among Americans

meteorologists, it has often struck me that Espy and Ferrel developed the deductive or theoretical side of the science more fully than Redfield or Loomis, whose interests were more largely inductive or observational. But it would be folly to criticise the work of any of these able men on account of their preference for one or the other kind of investigation. So with Thomson and Buchan: one approached the problem of the winds from the position of a physicist interested in applying the general laws of motion to the circulation of an atmosphere on a rotating planet; the other approaches the problem from the position of a patient observer who faithfully gathers records from all parts of the world and tabulates them. "Atmospheric circulation" would have suggested to Thomson a general physical discussion of the convectional movements of the atmosphere on the rotating earth; while to Buchan it served as the title to a report on the winds and pressures observed at the bottom of the atmosphere, with hardly any consideration at all of the upper currents that are essential parts of the circulation, and with only the briefest reference to the physical processes involved in the maintenance of the circulation.

Surely no objection can be made to the independent pursuit of either of these methods of investigation by any conscientious student, but it does seem to me fitting to protest against the inadequate consideration by an inductive investigator of the results reached by a deductive investigator. To my reading, the broad results arrived at in the Report on Atmospheric Circulation in the *Challenger Reports* give remarkable support to Ferrel's theory. The support would have been still stronger had the author of the report more explicitly asserted the existence of the Antarctic anticyclone and of the outflowing South-east winds beneath it, but the text of the *Challenger Report* gives so little emphasis to these significant features that the reader might easily pass them over unnoticed. Indeed, the implication of several passages points to the occurrence of a low-pressure centre about the South Pole; for example, in describing the Antarctic regions, Buchan wrote: "The observations of all the months show that there is a permanently low pressure over these regions, lower than is to be found anywhere else on the globe" (p. 52). Again: "Perhaps the most remarkable region of low pressure is in the Antarctic regions, which, remaining low throughout the year, plays the principal rôle in the wind systems bordering on and within the Antarctic circle" (p. 73). Certainly no reader of these sentences would infer that, as Murray has pointed out, there are "many indications that the extreme South Polar area is occupied by a vast anticyclone, out of which winds blow towards the girdle of low pressure outside the ice-bound region" (*Proc. Roy. Soc.* lxii., 1898, p. 424), and I do not doubt that the writer of the last preceding quotation would be greatly surprised to learn that he was therein strongly supporting Ferrel, who had, over thirty years before, come to the same conclusion, quoted Ross's observations, and given a rational explanation for them. Moreover, I believe that any one who carefully studies Ferrel's original publications would strongly dissent from Buchan's conclusions that Ferrel's theory is not accordant with the broad results reached in the *Challenger Report* and elsewhere, and that "both the surface winds and the upper aerial currents are diametrically opposed to the requirements of this [Ferrel's] theory."

When the rearrangement of pressures by the circumpolar winds is once perceived, it becomes as marked a characteristic of the atmosphere as the flattening around the Poles is of the rotating earth. It moreover gives a much-needed assistance towards the understanding of the movements of the upper currents as they obliquely approach and recede from the poles on the poleward gradients of the upper atmosphere, for this is also a subject that has been much misunderstood. Even if residual areas of high pressure remain around the poles, they exist in the lower atmosphere only: at a moderate altitude above sea-level, the gradients are certainly directed toward the poles through most of the temperate and all of the frigid zones; and the question has sometimes arisen as to how any currents can return towards the equator against these gradients, to compensate for the movement of other currents toward the poles. For example, in an important essay by Teisserenc de Bort on the distribution of pressure at successive altitudes above sea-level, he shows very clearly that at great heights the pressure decreases continually from equator to poles, and adds that Ferrel does not explain the equatorward gradients that are necessary for the return of the winds from the poles to the equator (*Ann. Bureau Centr. Mét. de France*, 1885, pt. iv.). Again, Supan, when reviewing Sprung's *Lehrbuch*, said that the distribution of pressure is the cause and not the effect of atmospheric motion, and as there is lower pressure in the polar regions than around the tropics, the hypothetical return currents from poles to equator cannot exist. Both these statements imply a misunderstanding on the part of the authors as to the behaviour of active circumpolar winds on poleward gradients. It is altogether dependent on the eastward velocity of a body of air whether the poleward gradient to which it is subject shall lead it to the pole or not; and it has been fully shown by physical meteorologists that the great eastward velocity gained by the upper currents on their strong poleward gradients suffices to give the currents an equatorward component of motion when they sink in their convectional circuits to the weaker poleward gradients at less altitudes. This is not a matter that can be presented in the lower schools, where only elementary notions of the atmospheric circulation can be introduced, but it is an integral part of the theories of Ferrel, Thomson, Oberbeck, and others, who succeed in giving rational explanation to the general movements of the winds. It is only natural that those whose interests do not lead them to an understanding of the relatively low pressures in the cold polar regions, where the simple convectional theory calls for persistent high pressures, should stop short of this more advanced phase of the problem.

What I most regret in this misunderstanding of Ferrel's work is that some brief paragraphs in my *Elementary Meteorology* seem to have been the cause of it; yet I cannot accept the entire responsibility of the misunderstanding, for several reasons. In the first place, it seems to me incumbent on those who would say that a theory of atmospheric circulation published by the late Prof. Ferrel is not in accord with the results reached in the *Challenger Report*, that they consult Ferrel's own essays before condemning them. In the second place, I do not think that any one who really understands the outline of Ferrel's theory, as set forth in my book, would say that the surface winds and the upper currents, as determined by observation, are diametrically opposed to

the requirements of the theory; for it is clearly set forth that "if the velocity of the circumpolar whirl near the pole were sufficiently reduced by continental obstructions, the high pressure due to cold might not be entirely overcome" (p. 129); and, moreover, the Arctic Polar winds are explicitly described as the result of the interference of the lands with the normal planetary circulation (pp. 129, 132): evidently, therefore, similar Antarctic winds might occur if a sufficient interference were found in the Southern Hemisphere. In the third place, although I was so careless as to say on one page: "In the Southern Hemisphere, where the land area is small, this defect, as it may be called, in the terrestrial circulation (*i.e.* Polar winds) does not appear as far as exploration has yet penetrated" (p. 132); another page contained the statement: "In passing to still higher latitudes [than those of the prevailing Westerly winds], about 60° in the Northern Hemisphere and somewhat farther from the equator in the Southern, winds from a polar source become more common; very little is known of them, and as they seem to be due to disturbance in the normal planetary winds caused by the lands, they will be briefly referred to in a later section" (p. 119). Unhappily, the later section only gave account of the Arctic winds, but a meridional diagram of the atmosphere (Fig. 34, p. 116) represented Polar winds in both polar regions.

However, I cannot excuse myself from having overlooked the observations of Antarctic voyages when saying that South Polar winds have not been observed "as far as exploration has yet penetrated." This error I must share with the author of another text-book, in which it is said that, "owing to the almost invariable low atmospheric pressure of the Antarctic regions, the winds there may be regarded as blowing constantly from the North-west," although, as Ferrel and Murray have both pointed out, the observations of Ross and others should have warned both of us from such statements.

It is by no means my desire, in calling attention to the place held by the Antarctic winds in Ferrel's theory, to imply that his work was beyond criticism, but merely to urge that it should be estimated at its true value. It certainly must be clear to every physical meteorologist that the convectional circulation of the atmosphere, as ordinarily stated, is seriously incompetent, for the most striking features in the distribution of atmospheric pressure are not accounted for by it. As long as the effect of the winds in modifying the distribution of pressure is left out of consideration, no broad understanding of atmospheric processes can be reached. I believe it will be the verdict of the meteorological world that, while various investigators have contributed certain shares toward this understanding, no one's share is so large as that which should be credited to William Ferrel.

DISCUSSION.

The **President** (Mr. F. C. Bayard) said they were much indebted to Prof. Davis for bringing the paper before the Society. It seemed to be really a criticism of the late Prof. Ferrel's book, *A Popular Treatise on the Winds.*

Mr. D. Archibald regretted the absence of Prof. Davis, whom he thought

the Society would be glad to have welcomed as a distinguished American Meteorologist. He (Mr. Archibald) had supported Ferrel's theories when they were first given to science, and he had not seen any reason to alter his views. Ferrel was a deductive philosopher, and it was saying much that when he had worked up an equation for a cyclone to a certain point, Prof. Loomis, who was purely an inductive philosopher, had adopted that equation. He had long noticed that Ferrel had reasoned out the question of the outward flow from the poles at the surface as a part of his theory of the general circulation. He remembered being asked by the editor of *Nature* to review Vol. II. of a treatise by the late Prof. W. Ferrel. It started with an equation of great magnitude, and he had to go through the whole of Vol. I. (of which there was but one copy in this country) before he could interpret that equation. With regard to polar cyclones, he had had some difficulty in accepting what has been designated by Ferrel as "cyclones with the cold centre," except with regard to the fixed cyclones round the poles; but since then he had thought that perhaps his scepticism only arose from the general inability of persons to rise, either physically or metaphorically, to the level of Ferrel's reasoning and the conditions he deduced. Kites or captive balloons would probably solve the matter. Most persons had not realised that there might be a cyclone with a cold centre—air descending, but rotation cyclonic. He thought that the exceptional boy mentioned in the paper was very like the average man, who, directly fact slightly disagreed with theory, gave the latter up as being unworthy of following. Another great point proved by Ferrel in atmospheric circulation was the universality of the deflection due to the earth's rotation on a current of air moving in any direction. Whenever a mass of air moved either along a meridian or a line of latitude, or between the two, it was deflected to the right over the Northern Hemisphere and to the left over the Southern Hemisphere. This seemed a feature difficult of acceptation by some meteorologists. Even the late Mr. Abercromby had some difficulty in that direction, so that it might be excusable in the ordinary scientist. With regard to the convectional theory, he did not think the dynamical effect of moist ascending air had had enough consideration in the past by those who were studying this question; the convectional ascent in one place and the convectional descent in another was a factor of considerable importance, quite apart from the motions due to expansion and overflow, or contraction and underflow, due to differences of temperature only. Another point which he was glad to see alluded to by Prof. Davis was the deflection of air away from the poles against the gradient. It was natural to suppose that air could not move apparently against the gradient, but it had been proved by Sprung and others that it could do so where friction was small. In the weather of the past week, when America had experienced blizzards and exceptionally severe weather, we on this side of the Atlantic were enjoying abnormal warmth. The former conditions might popularly be termed a polar current, while ours was a warm equatorial current; in other words, these currents represented opposite sides of a vast circulation of air of a cyclonic character. The current on the American side represented the outflow from the polar cap, while ours was a portion of the upward equatorial current brought to earth. Both were out of the place normally assigned to them on the ideal globe by Ferrel, but no one need cite such eccentricity as a proof that Ferrel's theory was incorrect. For his own part, he felt certain that in the absence of a good theory, such as that deduced by Ferrel, it was hopeless to attempt to draw many rational conclusions by pure induction alone from the mass of inchoate meteorological observations that had been collected all over the world.

Mr. C. Harding heartily endorsed the remarks of Mr. Archibald as to the value of Prof. Ferrel's work. Ferrel had applied an equation to the gale of

October 1886, and produced the same results as actually took place. At the Meteorological Office they had discussed observations for the Southern Hemisphere as far as possible, including Cape of Good Hope to New Zealand, also Cape of Good Hope to America across the Atlantic; but scientific men seemed to ignore the results, which, in his opinion, disproved the theories put forward as to the atmospheric circulation in those latitudes. There seemed little foundation for the statements as to low pressure and steady Westerly winds being prevalent. Among the observations, high readings were common as far south as lat. 55°. On the face of these results, it seemed that the original figures for those latitudes were half an inch out. The Meteorological Equator, varying as it did between 12° N. and 12° S., must have some effect on the position of areas of low pressure in the South Polar latitudes.

Capt. H. TOYNBEE, in a note to the Secretary, wrote: "When I read Nansen's book, the impression I got of the winds he experienced led me to suppose that he was under the influence of a zone of low pressure which changed its latitude with the seasons, and consequently he had a higher pressure to the northward of him. When his observations are thoroughly worked out, they will throw some light on the subject. I suppose it is allowed that areas of high pressure are fed by upper currents of cool descending air, and that areas of low pressure are fed by surface air, which has a tendency to rise where the pressure is lowest. I am sometimes inclined to think that in the V-shaped depression of the Northern Hemisphere the sudden shift to North-west with heavy rain is accompanied by a down-rush of air."

Mr. W. H. DINES, in a note to the Secretary, said: "I am fully in agreement with the conclusions drawn by the author of this paper, and consider that theoretical meteorology owes a greater debt to Ferrel than to any other man. The only point in which Ferrel's conclusions seem to have been seriously controverted is in his suggested cause of the cyclones of the temperate latitudes, but I have never doubted but that his theory (*i.e.* the convectional theory) is the correct one, and believe that balloon and kite observations will shortly prove this to be the case. I am glad that Prof. Davis has emphasised the tendency of a body moving to the east or west to turn to the right hand, as it is a very common mistake to suppose that the tendency only exists in a body moving to the north or south. The radius of the circle in which a body will move on the earth's surface if started and then acted upon by vertical forces only is given by the expression $\frac{6v \operatorname{cosec} \lambda}{\pi}$, where λ is the latitude, and v the velocity per hour of the moving body. The supposition is of course an impossible one, since the barometric gradient and friction are horizontal forces, and render the formula inapplicable, but the existence of the tendency fully explains the general course of the winds."

Major H. E. RAWSON, in a note to the Secretary, said: "William Ferrel's best friends are those who do not push his theory or his claims too far. He has done noble work, but he has not explained the facts of atmospheric circulation as we find them. And it was impossible that he should do so. The whole of the factors in the problem are not yet known. Nothing is more striking to an experimenter who is trying to reproduce with water what he sees going on in the atmosphere than the very different results he gets according as he varies the temperature of the water in the different layers he is working with. A simple experiment which anybody can try will illustrate this. Take any large vessel from which the outflow of water, through a centrally placed pipe at the bottom, can be regulated, and set up an eddy on the surface of the water in the vessel by letting it run out through the pipe. By sprinkling fine dust on the surface all that is going on can be watched. If the eddy is rotating with the hands of a

watch the pericyclonic ring recognised in the convectional circulation theory can be produced. It is much more difficult to obtain this with an anti-clockwise rotation. Introduce by a special pipe, before letting any water escape, different amounts of water of different temperatures at different depths, and, before an uniform temperature has been obtained, start the eddy on the surface. Not only will the eddy that is first formed be reversed, sometimes more than once, but several subsidiary eddies can be obtained which roll round the primary, much as a cyclone will roll round an anticyclone, or which coalesce and otherwise disport themselves as we see cyclonic and anticyclonic systems doing in the atmosphere. We are not representing what is going on at any centre of action in the atmosphere, but we obtain results which are remarkably like those experienced on the earth's surface. Ferrel's theory is admittedly less complete for the Northern than for the Southern Hemisphere owing to the distribution of land and sea. No theory can be complete which does not take into consideration the actions and reactions of stream-lines of different temperatures and densities and velocities travelling over a surface whose temperature is constantly varying. The above crude experiment suggests the reason why."

PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

January 18, 1899.

Ordinary Meeting.

FRANCIS CAMPBELL BAYARD, LL.M., President, in the Chair.

FREDERIC BEAUCHAMP WELLS, 1 Victoria Square, Cotham, Bristol, was balloted for and duly elected a Fellow of the Society.

January 18, 1899.

Annual General Meeting.

FRANCIS CAMPBELL BAYARD, LL.M., President, in the Chair.

Mr. F. DRUCE and Mr. J. S. HARDING were appointed Scrutineers of the Ballot for Officers and Council.

Mr. E. MAWLEY read the Report of the Council and the Balance-Sheet for the year 1898.

It was proposed by the PRESIDENT, seconded by Mr. E. MAWLEY, and resolved: "That the Report of the Council be received and adopted, and printed in the *Quarterly Journal*." [The Report will appear in the July number.]

It was proposed by Dr. R. BARNES, seconded by Dr. R. F. FOX, and resolved: "That the thanks of the Society be given to the Officers and other Members of the Council for their services during the past year."

It was proposed by Mr. H. S. WALLIS, seconded by Mr. J. STOKES, and resolved: "That the thanks of the Society be given to the Standing Committees and to the Auditors, and that the Committees be requested to continue their duties till the next Council Meeting."

It was proposed by Capt. D. WILSON-BARKER, seconded by Mr. R. BENTLEY, and resolved: "That the most cordial thanks of the Royal Meteorological Society

be communicated to the President and Council of the Institution of Civil Engineers, and also of the Royal Astronomical Society, for having granted the Society free permission to hold its Meetings in the rooms of their respective Institutions."

The PRESIDENT then delivered an Address on "THE GOVERNMENT METEOROLOGICAL ORGANISATIONS IN VARIOUS PARTS OF THE WORLD" (p. 69).

It was proposed by Mr. R. INWARDS, seconded by Mr. G. J. SYMONS, and resolved: "That the thanks of the Society be given to Mr. FRANCIS CAMPBELL BAYARD for his services as President during the past year, and for his Address, and that he be requested to allow it to be printed in the *Quarterly Journal.*"

The Scrutineers declared the following gentlemen to be the Officers and Council for the ensuing year:—

PRESIDENT.

FRANCIS CAMPBELL BAYARD, LL.M.

VICE-PRESIDENTS.

Capt. ALFRED CARPENTER, R.N., D.S.O., F.Z.S.
RICHARD HENRY CURTIS.
HENRY NEWTON DICKSON, F.R.S.E., F.R.G.S.
HUGH ROBERT MILL, D.Sc., F.R.S.E., F.R.G.S.

TREASURER.

CHARLES THEODORE WILLIAMS, M.A., M.D., F.R.C.P.

SECRETARIES.

EDWARD MAWLEY, F.R.H.S.
GEORGE JAMES SYMONS, F.R.S.

FOREIGN SECRETARY.

ROBERT HENRY SCOTT, M.A., D.Sc., F.R.S.

COUNCIL.

RICHARD BENTLEY, F.L.S., F.R.G.S.
FREDERICK JOHN BRODIE.
WILLIAM HENRY DINES, B.A.
WILLIAM ELLIS, F.R.S., F.R.A.S.
Major LAMOROCK FLOWER.
WILLIAM BULLER HEBERDEN, C.B.
RICHARD INWARDS, F.R.A.S.
BALDWIN LATHAM, M.Inst.C.E., F.G.S.
ROBERT COCKBURN MOSSMAN, F.R.S.E.
Rev. JAMES DUNNE PARKER, LL.D., F.R.A.S.
Sir CUTHBERT EDGAR PEEK, Bart., M.A., F.R.G.S., F.R.A.S.
Capt. DAVID WILSON-BARKER, F.R.S.E., F.R.G.S.

February 15, 1899.

Ordinary Meeting.

FRANCIS CAMPBELL BAYARD, LL.M., President, in the Chair.

DAVID NEZIAH WILLIAMS, 29 Tudor Terrace, Merthyr Tydfil, was balloted for and duly elected a Fellow of the Society.

The following communications were read :—

"REPORT ON THE PHENOLOGICAL OBSERVATIONS FOR 1898." By EDWARD MAWLEY, F.R.Met.Soc., F.R.H.S. (p. 133).

"THE CIRCULATION OF THE ATMOSPHERE." By Prof. WILLIAM MORRIS DAVIS (p. 160).

CORRESPONDENCE AND NOTES.

Deflection of Wind on H.M.S. "Worcester."—During a strong beam (North-north-west) wind accompanied by snow and sleet, I found that the direct horizontal wind current was only interfered with to a height of four feet above the ship's bulwarks. The particles of snow and sleet clearly indicated an upward current immediately on the edge of the bulwarks; this current shot up almost perpendicularly to a height of about three feet: between the heights of three and four feet the snowflakes bent over sharply and were carried in the main stream.

The cushion of air extended about a foot outwards from the ship's side, consequently a hand anemometer held well out over the ship's side was in the main air current.

In the case of an open bulwark, such as is now very general in ships, the deflection would be less; it would also be decreased by the wind striking the side at lesser angles.—D. WILSON-BARKER, *May* 4, 1899.

Great Radiation, March 22, 1899.—We have recorded this morning a very extraordinary frost for the time of year. There was a sharp frost yesterday, followed in the afternoon by a fall of snow equal to 2 inches average depth. The atmosphere became very clear, and, with a West wind and a falling barometer, we registered this morning as follows, the temperature having risen only a few degrees above the minima at 6 a.m.:—

	Minimum in Screen.	Radiation on Ground.
Upper Station	56°·1	42°·3
Lower Station	45°·5	27°·0

This is not only remarkable for the low reading, but for the marked difference in the two stations.

The air was extremely still, and is so now, though there was some wind yesterday.—L. CASTLE, Woburn Experimental Fruit Farm, Ridgmont, Beds, *March* 22, 1899.

Halo and Mock Suns seen at Sydney, December 9, 1898.—I was very much surprised, in December last, to receive reports from a number of persons stating that they had seen on December 9, just after 6 a.m., a well-defined display of mock suns and halos. This is the first appearance of such phenomena that I have heard of in Sydney.

Fortunately, it was observed and drawn by two friends,—one a civil engineer and the other a well-known artist,—and they between them made me a coloured drawing of what they saw. I could not get it published in colours here, but one of our local illustrated papers (*The Sydney Mail*) published a short notice of it.—H. C. RUSSELL, Sydney Observatory, *February* 21, 1899.

Ball Lightning.—In 1885 or 1886 I was staying at Zermatt, and one day interviewed Peter Taugwalder (the son of old Peter; both were Whymper's guides on the occasion of the first ascent of the Matterhorn), just as he had come to Zermatt across the Theodul Pass in a fearful thunderstorm. He stated to me

that a ball of fire came from the sky "ganz langsam" (quite slowly), and when close to the surface of the glacier, which is almost level on the Pass, it burst with a "furchtbarer Knall" (fearful report), and sent flashes of lightning "wie Aeste von Baeumen" (like branches of trees) darting all over the ice.

Now I doubt very much whether I should have the courage to photograph under such dramatic circumstances, though of course a picture of such an occurrence would be unique. What I did not quite see was that the ball of fire travelled slowly.—HENRY SPEYER, Reigate.

Climate of the Egyptian Sudan.—The limit of tropical rains, which runs across the White and Blue Niles a little above Khartum, and extends north-eastwards to the Upper Gash, divides the country into two sections differing widely in climate and consequently in their fauna and flora. To the north rain falls in a few heavy drops with thunder, and often fails altogether. The rains do not become regular till New Dongola is reached. The mean temperature at Wadi Halfa is 71° for January and 93° for July, the mean daily range is 28°·5, and the mean relative humidity is 32 per cent. In Gallabat, Gedaref, and Sennar, which lie just within the limit of tropical rains, the rainy season, "the Kharif," begins at the end of June and lasts till the end of December. Storms come from the east and south-east, and dry weather accompanies the constant North winds which set in at the end of October. At Khartum the Kharif assumes the form of thunderstorms from the east and south-east between July and September, with a few showers occasionally in May. In April the temperature reaches a maximum of 116°; the mean for the year is 84°, and the mean daily range is about 27°. The humidity is about 46 per cent in spring, and 60 per cent in the rainy season. In Kordofan the regular rainy season sets in in July, with South and South-west winds; and after that it usually rains every third or fourth day until the end of September, when the wind changes to the North, and by the end of January most of the wells are dry. Though the climate is not very hot, the elevation being considerable, intermittent fevers are very prevalent.

On the Upper Nile, between 6° and 9½° N. lat., the mean temperature is about 83°·5, and the first rains fall in the early part of March. At the equinox Southerly winds succeed to the Northerly winds prevailing in the winter half of the year. The rainfall amounts to 124 ins. At Lado the rainy season lasts from April to September, and December to February are the driest months. South winds are frequent at all seasons, and the annual movement of the temperature accords with that of the southern hemisphere. The annual mean is 80°, the absolute maximum 108°, and the absolute minimum 62°. The lower parts with the numerous water-channels are naturally unhealthy, but along the elevated watershed there are many districts which enjoy a healthy climate for such latitudes. Emin Pasha considered Makraka and the Seuli country suited even for European colonisation.—*Scottish Geographical Magazine.*

Climate of Iceland.—Dr. F. Thoroddsen, in a paper published in *The Geographical Journal*, gives the following account of the climate of Iceland:—

"The climate of the island is peculiarly suited for the development of large glaciers, the atmosphere being raw and cold and moist, the precipitation plentiful, and the amount of summer warmth but small. The precipitation is, however, very different in different parts of the island,—for instance, in Berufjord, in the south-east, the annual rainfall amounts to 42½ ins.; at Stykkisholm, in the west, to 25½ ins.; and on the island of Grimsey, off the north coast, to 16 ins. The precipitation is consequently heaviest on the south-east coast, and it is in that quarter of Iceland that the ice-clad mountain mass of Vatnajökull covers such a vast area of the plateau. In the south and south-west districts the weather is at all times very changeable and stormy. Snow seldom lies long in

winter on the lowland plains. Frost and thaw alternate several times in the course of a single day. Indeed, it often happens that for months together in the winter there is not a particle of snow to be seen on the lowlands of the south. On the other hand, it rains very frequently ; but whilst it rains on the lowlands it is often at the same instant snowing heavily in the elevated interior. For a series of years I have taken observations at Reykjavik of the number of days during which the ground has been covered with snow. The period is much shorter than one would suppose. In the winter of 1889-90, snow lay on the ground only 96 days ; in 1890-91, only 84 days ; in 1894-95, not more than 56 days. In the north of the island, on the contrary, snow lies for a much longer period.

"From observations made on the coast, it would appear that the climate of Iceland is typically insular, the winters being relatively mild, and the summers cool. Up on the plateau there is unquestionably a much greater difference between the winter mean and the summer mean ; but unfortunately we possess no data from that region. In the subjoined table, which was worked out at the Meteorological Institute in Copenhagen, I give observations taken at only one station on the plateau, namely Mödrudalur, which lies at an elevation of 1640 feet above the sea. As a single glance will show, the temperature there has a much greater range than at the other stations.

Mean Temperature for the period 1874-92.

Station.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
Stykkisholm (West Iceland)	28°·0	27°·3	27°·5	33°·4	39°·4	46°·2	49°·5	48°·6	45°·0	38°·8	33°·2	29°·0	37°·2
Eyrarbakki (South Iceland)	28·0	29·2	28·8	36·2	42·4	48·6	52·0	50·5	45·3	38·2	31·7	27·8	38·3
Berufjord (East Iceland)	29·2	29·5	28·0	33·8	38·5	44·0	47·0	46·2	43·5	38·0	33·4	29·8	36·7
Akureyri (North Iceland)	25·3	25·7	25·2	33·0	39·6	47·8	49·8	48·2	44·0	36·0	29·7	26·0	36·0
Vestmannaeyjar (off south coast)	33·8	34·3	34·2	39·0	43·5	47·7	51·0	49·8	46·0	41·2	36·8	33·6	41·0
Mödrudalur (on plateau)	17·4	19·8	18·0	36·3	35·8	47·0	48·6	44·4	38·7	29·7	22·8	18·2	31·4

"The temperature of Iceland varies very greatly from year to year, and also the mean of the separate months. For instance, take the month of March : at Stykkisholm the highest mean in a period of thirty-eight years was 39°·7 ; the lowest mean in the same period, 8°·1. This excessive variability in the temperature exercises great influence, not only upon the quantity of snow which falls, but also upon the altitude of the snow-line, to say nothing of the injurious effects it has upon the food-supplies of the people.

"The factor which exercises the greatest influence of all upon the climate is well known to be the Greenland drift-ice. When the ice appears off the north coast, the temperature immediately falls. In May and June, when the people who dwell in the south of the island perceive that it is snowing on the mountains, they at once take it as a sign that the dreaded drift-ice is about to invest the north coast. During the nineteenth century that coast has been free from ice about one year in every four or five. So long as the ice drifts backwards and forwards along the coast, the weather continues to be very changeable and stormy ; but once the ice gets fast to the land, the weather becomes more settled, though colder. The parts of the coast which are most subject to be blocked by the drift-ice are the north and east sides of the north-west peninsula (county of Strandir), and Langanes and Melrakkaslétta, at the north-east corner of the island. The effects of the presence of the drift-ice in those regions are manifested both in the greater extension of the snow-wreaths and in the cha-

acter of the vegetation. Owing to the constant coldness of the springs and the rawness of the summers, vegetation is extremely stunted and poor."

Quantity of Rain corresponding to given Depths of Fall.—Mr. A. J. Henry, Chief of Division of Records and Meteorological Data, Weather Bureau, Washington, gives some information on this subject in the *Monthly Weather Review.* He says: "It is sometimes necessary to know the total quantity of water corresponding to given depths of rainfall over an acre or even over a square mile. An acre, it will be remembered, contains 43,560 square ft., or 6,272,640 square ins., over which area a rainfall of an inch in depth would equal 6,272,640 cubic ins. of water, and we may convert the latter into gallons, barrels, or tons, as we please.

"We recently computed, for publication in the Year Book of an Agricultural Journal, a table giving the quantity of water corresponding to different depths of rainfall. A correspondent offers the criticism that the wine gallon of 231 cubic ins. should have been used instead of the Imperial (British) gallon of 277·463 cubic ins., as the former is the legal standard in the United States and the one commonly in use. We have therefore recomputed the table, giving the number of gallons per acre corresponding to given depths of rainfall in both measures, for the convenience of all concerned. One inch of rainfall = 22,607 imperial gallons per acre, or 27,154 United States gallons.

Quantity of Rainfall corresponding to given Depths.

		Gallons per acre.		
Depth of Rainfall.	Cubic inches per acre.	United States or Queen Anne.	Imperial (British).	Tons per acre (2000 pounds).
ins.				
·25	1,568,160	6,789	5,652	28
·50	3,136,320	13,577	11,303	56
·75	4,704,480	20,366	16,955	85
1·00	6,272,640	27,154	22,607	113
1·25	7,840,800	33,943	28,259	141
1·50	9,408,960	40,371	33,911	170
1·75	10,977,120	47,520	39,563	198
2·00	12,545,280	54,309	45,214	226
2·25	14,113,440	61,097	50,866	255
2·50	15,681,600	67,886	56,517	283
2·75	17,249,760	74,674	62,169	311
3·00	18,817,920	81,463	67,821	339
4·00	25,090,560	108,617	90,428	452
5·00	31,363,200	135,772	113,035	565
6·00	37,635,840	162,926	135,642	678

"The United States gallon, adopted by Congress in 1830, is identical with the wine gallon of Queen Anne. The latter, as well as the Winchester corn-gallon of 274½ cubic ins., and the standard ale gallon of Queen Elizabeth of 282 cubic ins., were abolished as standard measures of capacity in Great Britain in 1824, when the new imperial standard gallon containing 10 pounds weight of water at temperature 62° F., barometer 30 ins., was made the standard of capacity for liquid measures. At the same time, a cubic inch of distilled water, weighed in air by brass weights at the temperature of 62° F., the barometer at 30 ins., was declared to contain 252·458 grains, thus making the contents of the imperial gallon 277·274 cubic ins.

"A re-determination of the weight of a cubic inch of distilled water at the Board of Trade, Standards Department, London, 1889, by Mr. H. J. Chaney (*Philosophical Transactions of the Royal Society of London,* vol. 183 A, pp. 331-354), gave 252·286 grains as the true weight, instead of the hitherto

accepted value of 252·458, whence it follows that the capacity of the imperial gallon is 277·463 cubic ins., and the number of gallons per acre $= \frac{6,272,640}{277 \cdot 463} =$ 22,607, as above.

"The figures in the last column, tons per acre, were obtained by reckoning 200 imperial gallons to the ton of 2000 pounds."

RECENT PUBLICATIONS.

Annuaire de la Société Météorologique de France. April—September 1898. 4to.

This contains the proceedings at the meetings of the Society from March to July, as well as the following papers:—"Rayonnement de la terre sur un ballon": par Dr. T. Christen (7 pp.).—"Température de la mer": par Dr. Labat (4 pp.).—"Les Orages à Chateaudun": par E. Royer (4 pp.). This is a summary of the observations of thunderstorms during the 15 years 1883-97. During that period there were 374 days of thunderstorms, giving an annual mean of 25. The monthly means were: March 0·6, April 1·8, May 3·4, June 5·9, July 5·8, August 3·8, September 2·6, October 0·6. The author has also summarised the 374 days on which thunderstorms occurred according to the days of the week, and has obtained the following curious result:—

Sunday.	Monday.	Tuesday.	Wednesday.	Thursday.	Friday.	Saturday.
59	60	57	57	49	51	41

Indian Meteorological Memoirs. Vol. VI. Part IV. 1899. 4to.

This contains a paper, "Hailstorms in India during the period 1883-97, with a discussion on their distribution," by J. Eliot, F.R.S., Meteorological Reporter to the Government of India (89 pp. and 4 plates). Hailstorms in India are almost solely a phenomenon of the North-east or Dry Monsoon, as is shown by the following monthly summaries:—

Dry Monsoon.	No. of Hailstorms.	Wet Monsoon.	No. of Hailstorms.
December	57	June	22
January	91	July	4
February	112	August	2
March	241	September	5
April	203	October	4
May	72	November	10
Total	776	Total	47

Hailstorms occur in Kashmir, the North-Western Provinces, Rajputana, Central India, the Central Provinces, and Upper Burma, chiefly during the cool weather or first half of the Dry Monsoon, in connection with cold-weather cyclonic storms, and in the provinces of Bengal, Assam, Bombay, Madras, Sind, and the Punjab chiefly during the hot-weather period, or second half of the Dry Monsoon. Thunderstorms and hailstorms occur chiefly at the period when convective action is most vigorous. The conditions that accompany and appear to be essential to their formation are (1) high temperature and (2) large diurnal range of temperature. The large ascensional movement necessary for the formation of hailstorms appears to be produced either (1) by exaggerated hot-weather conditions in the open plains giving rise to unusually vigorous convective movement; (2) by a strong dry land current advancing seawards and

passing under a sea current and forcing the latter upwards ; or (3) by air movement from the plains across lines of hills. For example, the forced ascent of a mass of air moving across the Himalayas, the central axis of which rises to a height of 20,000 to 29,000 feet, would be sufficient to cool it much below the freezing point. As might be expected, hailstorms in the hot weather have a marked diurnal periodicity, occurring chiefly during the hours when the convective and other ascensional air movement necessary for their production is most vigorous and frequent, viz. from 3 to 8 p.m. ; 74 per cent of hailstorms in the hot weather occur between these hours. Hailstorms rarely occur to the south of 16° N. lat., whilst their distribution is very variable over the remainder of India, and evidently dependent upon local conditions.

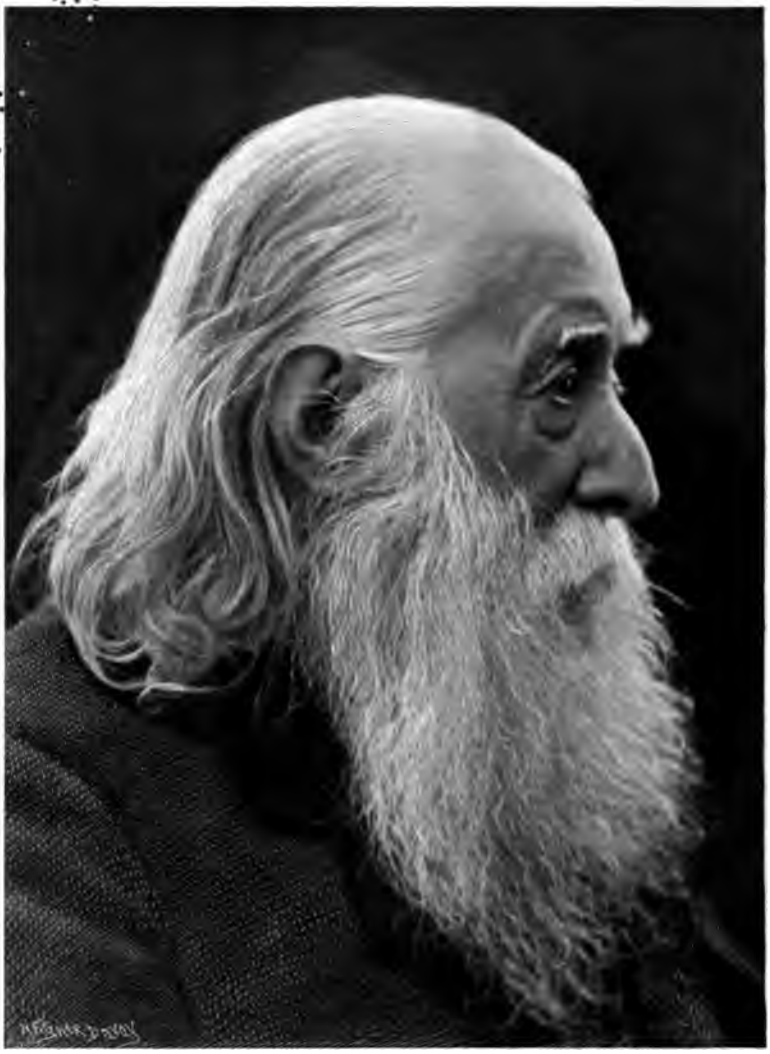
Meteorologische Zeitschrift. Redigirt von Dr. J. HANN und Dr. G. HELLMANN. September 1898—March 1899. 4to.

The principal articles are :—" Die Temperaturverhältnisse von Berlin" : von R. Börnstein und E. Less (12 pp.). The temperature was determined by means of a special thermograph by Fuess of Berlin—a sort of air- or rather gas-thermograph. It was on the roof of the High School for Agriculture in the Invaliden Strasse, at a height of 25·5 metres above the ground. The authors give a comparison between these values and those from a window screen at the level of 17·1 metres, as representing the usual German exposure, and the differences come out very slight. The authors therefore support the idea of Mr. E. J. Lowe, F.R.S., who used to maintain that an artificial soil could be provided on a flat roof by boxes filled with clay, and sown with grass seed. No reference to real open ground exposure is to be found in the paper. The observations refer to the 8 years 1890-97.—" Die Taifune in den ostasiatischen Gewässern" : von Dr. P. Bergholz (10 pp.). This is a translation of Dr. Doberck's "Laws of Storms" (Hong-Kong, 1898).—" Weitere Beiträge zu den Grundlagen für eine Theorie der täglichen Oscillation des Barometers" : von Dr. J. Hann (27 pp.). A translation of this paper is printed in this Journal (p. 40).—" Der Zusammenhang zwischen den Erscheinungen des Erdmagnetismus und den elektrischen Vorgängen in der Atmosphäre" : von Dr. W. Trabert (12 pp.). This paper is on the connection between the phenomena of terrestrial magnetism and the electrical processes in the atmosphere.—" Die Gewitterböe von Neunkirchen-Messbach im Odenwald am 15 Mai, 1898" : von Dr. G. Greim (6 pp.). This is an account of a very severe storm, accompanying a thunderstorm, which blew down a great quantity of timber in the Odenwald.—" Ueber die Temperaturänderungen auf- und absteigender Luftströme" : von Dr. W. von Bezold (8 pp.). This article is an answer to some criticisms of Herr Schmidt of Stuttgart, on the views propounded by Dr. von Bezold in his first paper on the thermodynamics of the atmosphere. The paper will repay perusal by those who deal with this question.—" Die Niederschlagsverhältnisse in Ungarn" (2 pp.). This note is accompanied by a new rain-map for Hungary by Herr O. Raum. The previous map by Dr. G. Schenzl appeared in 1885.—" Böenstudien gelegentlich des Gewitters von 22 Juni 1898" : von R. Börnstein (5 pp.). This is an investigation of a serious thunderstorm which passed over North Germany on the above date. It is illustrated by six barograms showing differences between the registrations of the different instruments. The particular interest of these curves, and of the map, lies in the evidence which they afford of a ridge, or, as the author calls it, a "nose," of high pressure accompanying the squall.—" Ein Beitrag zur Kenntniss des Höhenklimas tropischer Inseln" : von J. H. F. Kohlbrugge (30 pp.). This is a discussion by a medical man of the climate of a health station in Java, at a level of about 6000 feet. The treatment is very careful, and the results are compared with those of several other available

high-level stations in low latitudes. One of the principal features of the climate is very great dryness, the relative humidity going as low as 10 per cent. The paper deserves careful study from medical climatologists.—"Ergebnisse der internationalen Ballonfahrten": von H. Hergesell (10 pp.). This is a summary of the results of the ascents made by the Aeronautical Committee appointed in Paris, of which Dr. Hergesell is chairman. The special experiment was with a captive balloon kept at a level of about 2200 feet for 19½ hours over Strassburg. The results showed that while the range of temperature at the ground level was over 9°, it was less than 0°·2 at the level of the balloon. In the day time a range of 5° or 6° might occur above owing to vertical currents.—"Zur Charakteristik milder Winter": von G. Hellmann (4 pp.). The author has more than once discussed this question, but the mildness of last winter has induced him to take it up again. He maintains that it is much more probable that the summer will be warm if the preceding winter has been very mild, than when it has been only moderately mild; and he concludes with an appeal for weather charts covering a whole hemisphere, as the greatest desideratum of the present day.—"Fünfjährige Beobachtungen der Temperatur der Schneedecke in Tarnopol": von L. Satke (10 pp.). Tarnopol is in the east of Galicia, close to the Russian frontier; and the observations have been carried out on the surface of the snow, and also at depths of 5 and 10 centimetres. The observations are discussed according to wind direction, and also according to clear or cloudy sky.

Symons's Monthly Meteorological Magazine. October 1898—March 1899. 8vo.

The principal articles are:—"Heat and Drought in September 1898" (7 pp.). The deficiency of rainfall was most marked in the east and north-east of England, where the falls were generally about a quarter of an inch. The temperature was over 80° from the 3rd to 9th, and 14th to 17th. At Mr. Symons's station at Camden Square, where records extend over a period of 40 years, the absolute maximum of 91°·2 on the 8th is unprecedented in the month of September, and no other September had so many days above 85°, although in 1865 there were two more days above 80°.—"The Effect of Lightning on an Oak Tree": by J. G. Wood and L. Evans (2 pp.)—"The Aurora of September 9, 1898" (3 pp.).—"The British Association at Bristol, 1898" (10 pp.). This gives an abstract of the papers on meteorological subjects read before the Association.—"The Drought": by Dr. C. Kelly (1 p.).—"Admiral FitzRoy—The Genesis of Meteorology" (3 pp.). This is the reprint of an interesting article from the *Dundee Advertiser*.—"Climatological Records for the British Empire in 1897" (2 pp.).—"Floods in January 1899" (2 pp.).—"Extremes of Temperature in London and its Neighbourhood for 104 years" (2 pp.).—"On a recent Recurrence in Weather": by A. B. MacDowall (2 pp.).



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BORN 1801. DIED 1898.

Frontispiece, Quart. Journ. Roy. Met. Soc. vol. xxv. *From a Photograph by Mr. A. Strok.*

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THE PROLONGED DEFICIENCY OF RAIN IN 1897 AND 1898.

By FREDERICK J. BRODIE, F.R.Met.Soc.

[Read March 15, 1899.]

FOR several years past there has existed over England, and especially over our midland and south-eastern counties, a remarkable tendency in favour of dry weather. Proof of this would easily be seen by an examination of the rainfall records from almost any station in the area mentioned, but for present purposes it is sufficient to quote the state of affairs which has prevailed in the London district. From the observations made at Greenwich, it would appear that among the fourteen years immediately preceding 1897 there were no fewer than eleven with an annual rainfall amounting to less than the average, as deduced from the fifty-years' record 1841-90. In two of the years, viz. 1885 and 1886, the deficiency was trifling, but in some others it was very large, 1884 being one of the driest years on record.

A droughty tendency extending over so long a period could scarcely fail to have a very serious influence upon all underground waters, especially when we remember that in many cases the dry weather occurred in the winter months—a season when, from the engineers' point of view, a copious rainfall is most effective. The drought we are now about to review came, in fact, at a most inopportune time, its effects, which would in any case have been serious, being greatly aggravated by the state of things which had existed for so long previously.

In attempting a discussion of the recent deficiency of rain, one was met at the outset by the very difficult problem, how to define correctly the limits of time over which it extended. On careful consideration, it appeared that over England the dry weather may be said to have begun in May 1897, and to have ended about the middle of October 1898—a long and unwieldy period, lending itself, so far as I could see, to no

possible, or, at all events, to no satisfactory, method of subdivision. Further reflection seemed to show that, in order to deal with the matter in a convenient, workable manner, strict accuracy must give way to expediency; and, in the end, it was decided to review the conditions prevailing throughout the period of eighteen months commencing with April 1897 and ending with September 1898. The selection is, I am well aware, open to criticism, inasmuch as it includes, at the beginning, a month in which the rainfall was certainly in excess of the average; while it rejects, at the close, a fortnight in which the weather was about as dry as at any other time in the period. Equal, and perhaps more serious, objections might, however, be taken to almost any other period, the one selected having at least one merit, in that it supplies us with a modified, rather than an exaggerated, view of the conditions that actually prevailed. It has, moreover, the advantage of being easily divisible into three intervals of six months each, the first comprising the summer half-year of 1897, the second the winter half-year 1897-98, and the third the summer half-year of 1898.

In this manner, I propose, in the first place, to consider the rainfall conditions prevailing over the entire kingdom, as shown by returns from the stations (upwards of eighty in number) contained in the *Weekly Weather Report* of the Meteorological Office. The results obtained in this way are, of course, of a somewhat general nature; but, from the close agreement shown by the returns in districts where the stations are most numerous, it is clear that they may be relied upon as giving a very fair idea of the state of things existing over the country as a whole.

The series of monthly maps give, for the three half-yearly periods, the excess or deficit of rain existing each month, the departure from the average being shown by the usual plus and minus signs. A minus sign enclosed within a circle indicates that the rainfall was less than half the average. Figs. 7, 14, and 21 give the proportion of the average fall for the whole six months, expressed in percentage form, and shown graphically by various depths of shading; Fig. 22 depicting, in a similar way, the results for the entire period of eighteen months. The figures in Table I. give the actual values from which the charts were drawn, and also the number of days with rain, together with their differences from the average. In calculating the percentages, the averages employed are those for the thirty years 1866-95; the average numbers of days with rain is based upon the twenty years observations 1876-95. In the latter case the averages were only available for a limited number of stations.

First Period—April to September 1897.

April.—In this month there was, as we have already noticed, an excess of rainfall over the country generally, and in the south-western districts the excess was very large, some places having more than twice as much as their average quantity. A slight deficiency was, however, reported in the north of Scotland and the extreme south of that country, as well as at many stations in the north and east of England. (Fig. 1.)

May.—A deficiency was now shown over the country as a whole, and especially over the eastern and central parts of England, where the

amount was in some cases less than half the normal. In many parts of Scotland and the north of Ireland, as well as some of the English Channel stations, there was an excess, but this was, as a rule, not large. (Fig. 2.)

June.—Over the United Kingdom generally, this proved a wet month, and in many of the north-western districts it was very wet. Over the midland and south-eastern counties of England, however, there

FIG. 1.

FIG. 2.

FIG. 3.

was in many a slight deficiency, and in the north-west of Scotland a very large one; the amount at Stornoway being little more than one-seventh of the average, and only half that recorded in the driest June of the previous twenty-five years. (Fig. 3.)

July.—This was a very dry month, especially over the eastern and central parts of England, where the total amount of rain was in many places considerably less than half an inch. At Yarmouth, it was the driest July experienced for more than thirty years past. (Fig. 4.)

August.—In this month there was an excess of rain over the kingdom generally, and especially in the south-western districts. In the north of Scotland, however, and at isolated places in the north and east of England, a deficiency was reported. (Fig. 5.)

FIG. 4.

FIG. 5.

FIG. 6.

September.—Owing to local thunderstorms, the amount varied greatly in different localities. Over England as a whole, the fall was in excess of the average, but at many stations in the central and southern districts

TABLE I.—RAINFALL EXPERIENCED OVER THE BRITISH ISLANDS DURING EACH OF THE SEMI-ANNUAL PERIODS APRIL–SEPTEMBER 1897, OCTOBER 1897–MARCH 1898, AND APRIL–SEPTEMBER 1898; AND ALSO DURING THE ENTIRE EIGHTEEN MONTHS APRIL 1897–SEPTEMBER 1898.

Stations.	April–Sept. 1897.				Oct. 1897–March 1898.				April–Sept. 1898.				April 1897–Sept. 1898.			
	Days with Rain.		Total Fall.		Days with Rain.		Total Fall.		Days with Rain.		Total Fall.		Days with Rain.		Total Fall.	
	No. of Days.	Difference from Average.	Total.	Percent. of Average.	No. of Days.	Difference from Average.	Total.	Percent. of Average.	No. of Days.	Difference from Average.	Total.	Percent. of Average.	No. of Days.	Difference from Average.	Total.	Percent. of Average.
SCOTLAND, N.			ins.	%			ins.	%			ins.	%			ins.	%
Sumburgh Head	108	0	14·95	102	142	− 6	24·63	110	109	+ 1	14·50	99	359	− 5	54·08	104
Stornoway	108	− 6	15·90	85	151	+ 9	35·78	127	130	+16	22·92	122	389	+19	74·60	114
Wick	106	+ 5	10·12	79	113	− 7	8·95	57	105	+ 4	13·07	102	324	+ 2	32·14	78
Lairg	99	+10	10·65	67	129	+25	19·66	94	103	+14	19·55	124	331	+49	49·86	95
Glencarron	108	?	36·99	109	139	?	59·73	115	126	?	41·26	122	373	?	137·98	115
Fort Augustus	107	?	19·27	116	129	?	30·12	120	104	?	16·41	98	340	?	65·80	112
Fort William	109	?	33·38	115	133	?	55·10	115	116	?	33·43	115	358	?	121·91	115
SCOTLAND, E.																
Nairn	101	+ 6	9·87	78	108	+ 7	12·05	101	89	− 6	11·70	93	298	+ 7	33·62	90
Aberdeen	104	+ 4	14·71	100	100	−13	12·11	75	103	+ 3	14·30	98	307	− 6	41·12	90
Braemar	106	+ 6	17·62	105	98	− 8	15·77	82	100	0	14·43	86	304	− 2	47·82	91
Ochtertyre	96	+11	21·83	123	105	+ 6	16·78	70	86	+ 1	17·47	98	287	+18	56·08	94
Leith	88	− 1	12·53	99	72	−19	6·66	62	80	− 9	10·82	85	240	−29	30·01	83
Marchmont	92	?	14·34	83	95	?	11·38	65	87	?	12·91	75	270	?	38·63	74
ENGLAND, N.E.																
Alnwick Castle	94	+ 5	15·73	105	109	+ 8	11·86	74	110	+21	10·63	71	313	+34	38·22	83
Durham	86	− 6	11·82	84	85	−17	8·47	60	83	− 9	7·94	56	254	−32	28·23	67
Shields	85	0	11·29	88	71	−23	7·66	63	69	−16	9·29	72	225	−39	28·24	74
Scarborough	71	−19	12·19	88	71	−34	9·18	64	55	−35	11·40	82	197	−88	32·77	78
York	83	− 6	12·77	94	87	−14	8·85	72	70	−19	12·96	95	240	−39	34·58	87
Spurn Head	76	?	10·12	101	81	?	7·82	74	70	?	7·99	80	227	?	25·93	85
ENGLAND, E.																
Hillington	80	− 9	14·43	103	83	−28	10·12	76	72	−17	9·66	69	235	−54	34·21	83
Yarmouth	82	− 7	10·73	82	75	−32	7·07	51	65	−24	9·47	72	222	−63	27·27	68
Geldeston	78	?	9·38	78	81	?	7·88	64	68	?	10·58	88	227	?	27·84	77
Cambridge	65	−19	11·54	91	65	−24	5·84	55	69	−15	9·50	75	199	−58	26·88	75
Rothamsted	84	?	11·44	81	86	?	7·68	53	73	?	8·36	59	243	?	27·48	64
MIDLAND COUNTIES.																
Bawtry	82	?	10·69	81	69	?	6·92	57	73	?	11·23	85	224	?	28·84	75
Loughborough	76	?	11·64	87	88	?	8·37	67	77	?	9·90	74	241	?	29·91	76
Stamford	81	?	10·75	79	81	?	7·12	56	67	?	9·82	72	229	?	27·69	69
Cheadle	89	0	17·21	101	93	−12	12·88	76	81	− 8	14·98	88	263	−20	45·07	88
Shirley	96	?	15·16	?	96	?	9·83	?	84	?	13·00	?	276	?	37·99	?
Churchstoke	91	+ 1	10·91	77	88	−10	12·36	72	82	− 8	11·95	85	261	−17	35·22	78
Hereford	86	+ 4	13·62	103	76	−21	8·57	62	74	− 8	9·99	75	236	−25	32·18	80
Cirencester	86	+ 4	16·31	105	80	−11	9·33	57	73	− 9	10·50	68	239	−16	36·14	79
Oxford	72	−10	14·41	111	70	−21	7·34	58	67	−15	7·58	58	209	−46	29·33	76
ENGLAND, S.																
London (Brixton)	80	0	11·76	94	75	−14	7·07	57	63	−17	6·32	51	218	−31	25·15	67
North Foreland	74	?	8·98	?	80	?	7·77	?	56	?	8·69	?	210	?	25·44	?
Dungeness	75	?	7·67	67	72	?	5·63	36	55	?	6·91	60	202	?	20·21	53
Hastings	76	− 6	13·52	107	73	−32	9·40	56	59	−23	9·89	78	208	−61	32·81	78
Southampton	82	+ 1	13·73	98	77	−17	10·57	61	74	− 7	9·89	71	233	−23	34·19	76
Hurst Castle	81	+ 2	12·77	100	70	−26	9·53	59	59	−20	8·68	68	210	−44	30·98	74
Shaftesbury	84	?	15·12	94	83	?	12·76	70	73	?	12·34	77	240	?	40·22	80

TABLE I.—Rainfall experienced over the British Islands—*Continued.*

tions.	April–Sept. 1897.				Oct. 1897–March 1898.				April–Sept. 1898.				April 1897–Sept. 1898.			
	Days with Rain.		Total Fall.		Days with Rain.		Total Fall.		Days with Rain.		Total Fall.		Days with Rain.		Total Fall.	
	No. of Days.	Difference from Average.	Total.	Percent. of Average.	No. of Days.	Difference from Average.	Total.	Percent. of Average.	No. of Days.	Difference from Average.	Total.	Percent. of Average.	No. of Days.	Difference from Average	Total.	Percent. of Average.
nd, W.			ins.	%			ins.	%			ins.	%			ins.	%
: . .	117	+ 6	26·20	90	140	+13	38·06	81	126	+15	32·53	112	383	+34	96·79	92
v . .	97	+ 1	21·18	115	106	+ 1	17·02	80	100	+ 4	16·98	93	303	+ 6	55·18	95
an .	101	+ 9	17·25	103	102	− 5	12·53	61	90	− 2	10·99	65	293	+ 2	40·77	76
. .	105	?	24·97	111	119	?	34·61	100	104	?	21·44	95	328	?	81·02	102
. .	124	?	21·67	?	123	?	26·25	?	109	?	20·07	?	356	?	67·99	?
. . .	90	?	20·33	119	109	?	21·06	87	88	?	16·69	98	287	?	58·08	100
d, N.W.																
urst .	103	+ 4	27·37	121	100	− 10	27·28	108	95	− 4	18·54	82	298	− 10	73·19	104
ool .	89	?	16·75	105	96	?	17·03	95	83	?	16·06	101	268	?	49·84	100
ster .	93	− 2	18·28	98	98	− 7	20·50	107	89	− 6	14·94	80	280	− 15	53·72	95
ol . .	91	+ 1	14·40	100	90	− 11	12·47	86	80	− 10	14·41	100	261	− 20	41·28	95
lno .	94	+ 10	14·06	102	89	− 8	15·54	89	83	− 1	16·57	121	266	+ 1	46·17	103
ad . .	94	+ 1	14·55	103	96	− 16	20·34	101	89	− 4	15·18	107	279	− 19	50·07	104
d, S.W.																
ery .	106	?	22·03	103	114	?	24·29	84	94	?	20·30	95	314	?	66·62	93
ke .	91	+ 1	16·55	114	89	− 24	17·05	82	72	− 18	13·93	96	252	− 41	47·53	96
. .	85	?	21·47	129	75	?	12·19	66	69	?	12·60	76	229	?	46·26	89
on . .	112	?	29·43	127	97	?	21·00	70	82	?	20·85	90	291	?	71·28	93
oton .	97	?	18·49	116	89	?	15·06	76	66	?	11·53	72	252	?	45·08	87
th . .	105	+ 12	18·53	97	93	− 24	19·64	69	76	− 17	12·43	65	274	− 29	50·60	76
th . .	95	+ 9	18·08	115	91	− 12	14·04	67	68	− 18	12·61	80	254	− 21	44·73	86
Point .	89	?	17·12	142	98	?	13·55	77	78	?	10·39	86	265	?	41·06	99
nd, N.																
Head .	109	?	18·21	?	118	?	15·58	?	116	?	14·40	?	343	?	48·19	?
derry .	122	?	20·85	115	122	?	20·14	92	124	?	19·68	109	368	?	60·67	104
. .	114	+ 4	25·03	142	113	− 9	19·33	100	98	− 12	20·37	116	325	− 17	64·73	118
et . .	112	?	23·80	115	145	?	22·12	74	138	?	18·21	88	395	?	64·13	90
Castle .	128	+ 11	23·13	120	116	− 13	20·87	95	123	+ 6	20·16	105	367	+ 4	64·16	106
. .	112	+ 8	18·89	123	105	− 4	14·71	93	101	− 3	17·69	115	318	+ 1	51·29	110
adee .	104	+ 4	16·92	113	107	− 5	13·60	83	106	+ 6	16·71	112	317	+ 5	47·23	102
nd, S.																
. .	108	+ 13	14·91	111	94	− 8	11·94	85	89	− 6	13·41	100	291	− 1	40·26	98
town .	107	+ 10	18·24	112	90	− 18	15·73	96	95	− 2	20·14	124	292	− 10	54·11	111
y . .	100	?	20·53	134	86	?	16·99	98	87	?	16·28	106	273	?	53·80	112
Point .	93	+ 5	17·68	88	89	− 15	22·10	82	78	− 10	20·12	100	260	− 20	59·90	89
. .	118	+ 3	26·41	112	125	− 8	31·98	99	111	− 4	21·24	90	354	− 9	79·63	100
y . .	119	?	25·01	?	104	?	32·91	?	98	?	24·12	?	321	?	82·04	?
. .	109	?	25·78	?	91	?	21·90	?	90	?	19·97	?	290	?	67·65	?
el lands.																
. Mary's)	99	+ 3	13·97	101	101	− 20	14·03	70	78	− 18	10·36	75	278	− 35	38·36	80
. .	95	+ 11	18·37	134	95	− 19	13·35	65	83	− 1	12·11	89	273	− 9	43·83	92

there was a slight deficiency, and in the western and central parts of Ireland a somewhat large one. (Fig. 6.)

The Entire Six Months.—From the foregoing summary, it will be seen that the period comprised three months in which the rainfall was mostly in excess of the average, one month with great local variations, due largely to the presence or absence of thunderstorms, and two months with a considerable deficiency of rain, especially over our Eastern

FIG. 7.

and Midland counties. Taking the period as a whole, we see, from Fig. 7, that the total rainfall was in excess of the average over nearly the whole of Ireland, the south-west and north-west of England, and all the more central and southern parts of Scotland; the excess amounting to as much as 42 per cent at Edenfel (Omagh) and Prawle Point, 34 per cent at Kilkenny and Jersey, and 29 per cent at Clifton. In the north of Scotland, and at many stations in the northern, eastern, and central parts of England, there was a somewhat large deficiency, the driest of

the *Weekly Weather Report* stations being Lairg, in Sutherland, with only 67 per cent of the average rainfall, Churchstoke with 77 per cent, Geldeston with 78 per cent, and Wick and Stamford with 79 per cent. The number of days with a measurable quantity of rain was mostly in excess of the normal, but a general deficiency was shown in the north and east of England. At Cambridge there were only 65 days as against an average of 84, and at Scarborough only 71 as against an average of 90.

Second Period—October 1897 *to March* 1898.

October.—In this month the rainfall was less than the average in all localities excepting the south of Ireland, the deficiency being very large over Great Britain as a whole, and especially in the south of England. Over our south-eastern counties the total amount was, as a rule, less than half an inch, and in some places less than a quarter of an inch, the month proving at many of the southern stations the driest October on record. At Greenwich the total fall (0·48 in.) was very little more than half that recorded in the driest October (1879) hitherto experienced back to the year 1841. (Fig. 8.)

November.—Over the kingdom as a whole, this was again a dry month, the only districts with any excess of rain being the south of Ireland and the northern parts of England and Wales. In the south and east of England the amount was, as a rule, less than half the normal. (Fig. 9.)

FIG. 8.

FIG. 9.

FIG. 10.

December.—In many of the northern and eastern parts both of England and Scotland there was again a deficient rainfall, but in other localities the amounts were in excess of the average, the excess being large at several of the western stations. (Fig. 10.)

January.—In addition to being a very dry month, this was also a very mild one, a somewhat unusual combination in the winter time. Over the United Kingdom generally the rainfall was considerably less than the average, the driest regions being again the eastern, central, and southern. At some stations in our Midland and Southern counties, and also at Marchmont, the month proved the driest January for more than thirty years past. In the north-west of England, however, and the west and north of Scotland, there were places with an excess of rain, and at isolated stations the excess was rather considerable. (Fig. 11.)

February.—In this month the rainfall was again generally deficient, and especially in the eastern parts of Great Britain, where the total amount was in many places less than half the normal. At some of the

FIG. 11.

FIG. 12.

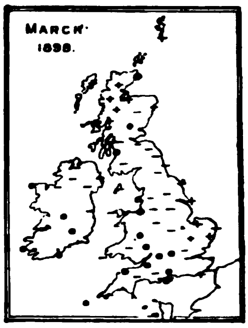

FIG. 13.

English Channel stations, however, there was a slight excess, and in the north-western parts of the kingdom generally a somewhat large excess. (Fig. 12.)

FIG. 14.

March.—Over the country as a whole dry weather was again prevalent, the rainfall at many of the western and southern stations being less

than half the average. At some places in the east and south-east of England there was, however, a slight excess, and in the north-west of Scotland the month was again a wet one. (Fig. 13.)

The Entire Six Months.—Over the country as a whole (Fig. 14) this period was remarkably dry, the only regions with any excess of rain being the north-west of Scotland and some portions of north Wales and of the north-west of England. Over Ireland and the north-western parts of Great Britain as a whole, the deficiency was not great, but elsewhere it was very large, the total fall in all but the extreme western and northern parts of England and also in the south and south-east of Scotland amounting, as a rule, to less than 70 per cent of the average. The driest localities of all were the Eastern, Midland, and Southern counties of England, where less than 60 per cent of the average rainfall was measured; the smallest proportions shown by the returns being 51 per cent at Yarmouth, 53 per cent at Rothamsted, 55 per cent at Cambridge, and 56 per cent at Stamford and Hastings. At Oxford, where the total fall amounted to 7·3 ins., or 58 per cent of the average, the winter six months were among the driest on record, the only winters in the past years with a smaller rainfall being those of 1890-91 and of 1879-80. At Greenwich, where the total amount was 6·9 ins., or 59 per cent of the average, the period was also one of the driest on record; the only winter half-years with a smaller rainfall, going back to 1841, being 1879-80, with a total of 5·5 ins., and 1858-59, with a total of 6·7 ins. In the six months ending 1879-80, the rainfall at Greenwich did not amount to more than 47 per cent of the average. The number of days with rain was less than the average at all but a few of the Scottish stations, the deficiency being very large at many places in the east and south-east of England. At Scarborough there were only 71 as against an average of 105, at Hillington 83 as against 111, at Hastings 73 as against 105, and at Yarmouth 75 as against 107.

Third Period—April to September 1898.

April.—In the east and south of England there was a deficiency of rain—small in many places, but large in London and some other parts of our south-eastern counties. Elsewhere, the fall was in excess of the

FIG. 15.

FIG. 16.

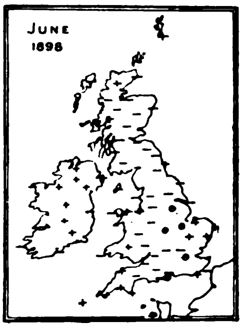

FIG. 17.

average, and in the eastern and central parts of Scotland the excess was very large. (Fig. 15.)

May.—Over the United Kingdom generally, this was a wet month, and in the west and south very wet, the total rainfall being in many places more than twice as much as the average. The only regions with any general deficiency were the extreme north of England and the central and southern parts of Scotland. (Fig. 16.)

June.—Over Great Britain as a whole, the rainfall was less than the normal, and at some of the English stations, including London, less than half the normal. An excess was, however, reported in many western parts of the kingdom, and also in the east of England, the large aggregate in the latter district being due entirely to a heavy fall which occurred on the 9th of the month. Had it not been for this one wet day, the month's rainfall in our eastern counties would also have shown a deficiency. (Fig. 17.)

July.—This proved an extremely dry month, especially in Ireland, Wales, and the south of England, where the total rainfall was, in many instances, considerably less than one-fourth of the average. In some parts of Ireland and at nearly all stations in the south-west of England the fall was the smallest registered in July for twenty-five or thirty years past, or, in fact, since the records commenced. (Fig. 18.)

Fig. 18.

Fig. 19.

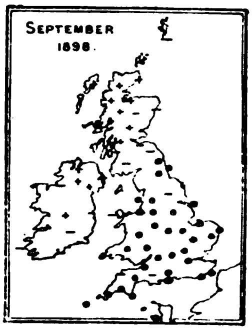

Fig. 20.

August.—In the eastern and southern parts of Great Britain the rainfall was again deficient, and at some places in the south of England it amounted to less than half the normal. Over the northern and central parts of England, however, as well as in Ireland and the west and north of Scotland, there was an excess. (Fig. 19.)

September.—Over the kingdom as a whole, this proved an extremely dry month, the rainfall over the northern, eastern, and south-eastern parts of England being in many places the smallest ever recorded in September. At Greenwich, where only 0·3 in. fell, there had not been so dry a September since 1865, or, with that exception, in any year since 1841. The only regions with any excess were the north of Ireland and the west and north of Scotland. (Fig. 20.)

The Entire Six Months.—Two of the six months were excessively dry, and in the southern parts of England at least two others had a deficiency of rainfall. Taking the period as a whole (Fig. 21), the rainfall over our Eastern, Midland, and Southern counties amounted to less than 80 per cent of the average, and in the South-eastern counties to less than 60

per cent; the smallest proportions of all being 51 per cent in London (Brixton), 56 per cent at Durham, and 58 per cent at Oxford. At Greenwich, where the total rainfall was only 7·8 ins., or 61 per cent of the average, the summer six months were among the driest on record, the only years with a smaller aggregate being 1893 with 7·3 ins., 1870 with 6·8 ins., and 1844 with 7·3 ins. Over the greater part of Ireland and the west and north of Scotland, as well as at some stations in north

FIG. 21.

Wales and the north-west of England, the rainfall of the period was in excess of the average, the wettest stations being Lairg and Parsonstown, with 24 per cent, Stornoway and Glencarron, with 22 per cent, and Llandudno, with 21 per cent, more than their due share. The number of days with rain was more than the average in Scotland and the north of Ireland, but less elsewhere. Hastings had only 59 rainy days as against an average of 82, Yarmouth 65 as against an average of 89, and Scarborough 55 as against an average of 90.

The Eighteen Months—April 1897 *to September* 1898.

The general results for the whole eighteen months are given in Fig. 22. A cursory glance shows, as one would, indeed, gather from the foregoing summary, that over the greater part of Ireland and the north-western parts both of England and Scotland the rainfall was above the average; the wettest stations of all being Edenfel (Omagh) with an

excess of 18 per cent, Glencarron and Fort William with an excess of 15 per cent, and Stornoway with an excess of 14 per cent. At stations in the north-west of England the excess was nowhere more than 4 per cent, while in the extreme south of Ireland there appears to have been a deficiency, amounting to as much as 11 per cent at Roche's Point. In estimating the extent of the drought in other regions, it must not be forgotten that we are now dealing with a very long period, in which the chances in favour of a large deficiency are naturally reduced in a very material degree. As a matter of fact, it appears that in the western and northern districts, other than those already mentioned, the deficiency of

FIG. 22.

rain was not very great; an exception being shown, however, in the north-east of England, and, locally, at Ardrossan. In the former locality the amount was in most places at least 20 per cent less than the average, while at Durham it was as much as 33 per cent less. Over nearly all the eastern and central parts of England, and in our southern counties east of Devon and Somerset, there was also a deficiency, amounting to at least 20 per cent; while in the south-eastern and south Midland counties there was a deficiency of at least 30 per cent; the driest of the *Weekly Weather Report* stations being Rothamsted with only 64 per cent of the average amount, London (Brixton) with only 67 per cent, Yarmouth with 68 per cent, and Stamford with 69 per cent. In addition to these I gather, from information kindly supplied by Mr. Symons, that at Sevenoaks the percentage value was only 64, and that at Enfield it

was as low as 63. The number of days with rain showed an excess at many northern stations, but by no means a general one. Elsewhere

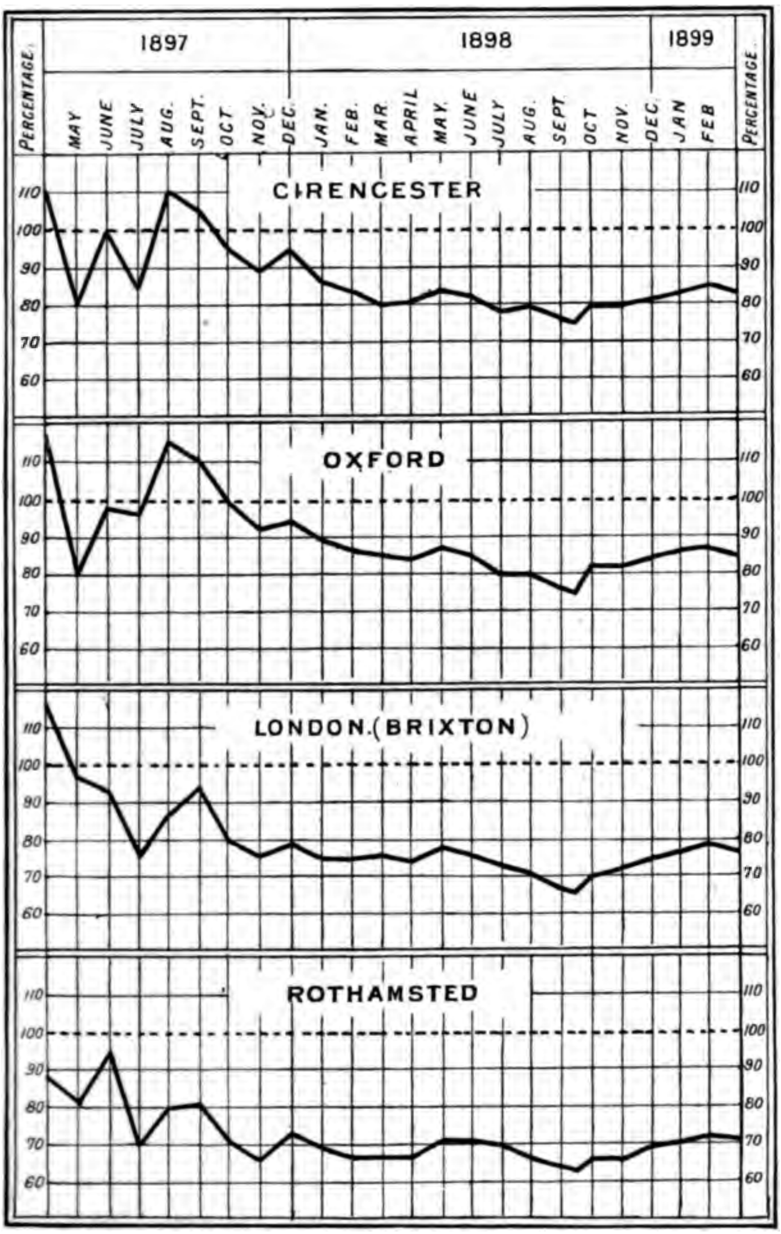

FIG. 23.

there was a deficiency, varying greatly in different places, but, of course, mostly large in the regions where the total rainfall was slight. At

Cambridge there were only 199 such days as against an average of 257; at Hastings, 208 against an average of 269; and at Yarmouth, 222 against an average of 285; while at Scarborough the number was only 197 as against an average of 285.

The Progress of the Drought.

The progress of the drought at four English stations is shown in the diagram Fig. 23, the stations chosen being Cirencester, Oxford, London (Brixton), and Rothamsted. Commencing with April 1897, the proportion borne by the accumulated rainfall to the accumulated average was worked out at the end of each month in percentage form, and the results plotted on the diagram. The diagram, therefore, shows the progressive state of affairs throughout the whole of the period. In order to see what has since been done in the way of making up the deficiency of rain, the curves are continued up to the present time, or rather up to the end of February 1899. It must not be forgotten that, with the progress of time, the significance of the downward movement shown by the curves increases very materially; a deficiency, say of 20 per cent, continued over twelve months or more being, as we have already remarked, a very different thing from a similar deficiency lasting through a much shorter period. At each of the stations Cirencester, Oxford, and London, it will be seen that the period started with an excess of rain, but that at Rothamsted there was a deficiency from the very first. The movements during the next four or five months were rather irregular, but after September 1897 a slow but steady increase in the severity of the drought appears to have set in, shown clearly by the gradual downward movement of the curve. At all four stations the lowest point was reached about the middle of October, the accumulated rainfall up to the 15th of that month having been specially worked out. At Cirencester and Oxford the total amount for the whole period of 18½ months was then 75 per cent of the average; in London it was only 66 per cent, and at Rothamsted only 63 per cent of the average. Since then the curves show a gradual recovery, but up to the end of February the proportion of the average rainfall for nearly two years was only 72 per cent of the average at Rothamsted and 79 per cent in London. The present month (March) is not yet half through, but so far there has again been a great deficiency in these parts, and unless a change soon takes place the completion of the curve will certainly not show any further rise.[1]

Comparison with Previous Dry Periods.

In order to obtain some idea as to the relation existing between this and other long dry periods, I have extracted from the Greenwich returns a list of all occasions since 1841 in which a general tendency for drought has prevailed for at least six months, the results being given in Table II. The run of dry weather includes in many cases individual months in which the rainfall was above the average,

[1] The curves have since been continued up to the end of March 1899, and now cover a period of exactly two years. At all four stations the proportion of the average rainfall at the close of March was smaller than at the end of February, the decline amounting to 1 per cent at Rothamsted, and to 2 per cent at Cirencester, Oxford, and London.

but a consecutive run of two or three wet months has been taken to end the drought for the time being. From the figures given in the table, it would appear pretty evident that, for length and severity combined, the recent spell of dry weather was the most remarkable experienced at Greenwich since at least the year 1841. During this period of nearly 60 years there were 5 periods in which the deficiency of rain was more prolonged than in the case under review, but in each instance the proportion of the average fall was greater, allowing even for the increased length of the period. It is worthy of note that of the 21 periods given in the table, no fewer than 7 occurred during the last 15 years, while 8 occurred between the years 1844 and 1862, leaving only 6 to be accounted for in the 20 years 1863-82. At Greenwich the period of 58 years ending with 1898 may apparently be divided into three—one lasting from 1844 to 1862 with a tendency for drought, another lasting from 1863 to 1882 with a tendency for wet weather, and the third lasting from 1883 to the present time with a tendency for drought. Continuing the statement made at the beginning of the paper, we may say that out of the 16 years ending 1898 there were at Greenwich no fewer than 13 with a deficiency in the annual rainfall, that in 6 of these the deficiency was large, and that in 2 of them, viz. the years 1884 and 1898, it was very large.

TABLE II.—CONSECUTIVE PERIODS OF SIX MONTHS OR MORE WITH A GENERAL DEFICIENCY OF RAIN AT GREENWICH.

YEARS.	Limiting Dates.	No. of Months covered by Period.	No. of Months with Rainfall less than Average.	Total Rainfall in Period.	Proportion of Average Amount.
				ins.	%
1844	April to September	6	6	7·29	57
1846–48	February 1846 to January 1848	24	20	41·28	84
1849–50	October 1849 to December 1850	15	11	26·13	83
1851–52	September 1851 to May 1852	9	8	10·94	62
1853–56	November 1853 to March 1856	29	23	50·18	86
1856–57	October 1856 to July 1857	10	7	14·15	71
1858–59	August 1858 to March 1859	8	8	9·01	55
1861–62	April 1861 to February 1862	11	10	18·20	79
1862–64	June 1862 to August 1864	27	20	44·02	79
1867–68	October 1867 to November 1868	14	10	24·23	82
1870	April to September	6	6	6·80	53
1873–75	March 1873 to May 1875	27	19	46·31	85
1876	April to October	7	6	10·35	67
1881–82	April 1881 to August 1882	17	13	33·16	95
1883–85	March 1883 to January 1885	23	17	36·80	77
1887–88	January 1887 to May 1888	17	14	26·58	80
1890–91	September 1890 to June 1891	10	8	12·21	62
1892–93	November 1892 to September 1893	11	9	15·29	70
1895	January to October	10	9	14·33	70
1896	January to November	11	9	19·42	85
1897–98	April 1897 to September 1898	18	14	25·77	69

Effects of the Drought.

The influence of the drought on the agricultural season of 1897 was very slight, owing probably to the fact that at times when the weather

was not very dry it was often very wet, the copious rains in April and June, for example, enabling the country to pass fairly well through the droughts of May and July. Towards the end of July, however, rain was greatly needed by the crops and pastures, while in November the ground became so hard that all tillage operations were seriously delayed. In 1898 the effect of the continued drought on agriculture was more severely felt, especially in the latter part of the season. As a proof of this, I would quote some remarks by Mr. Mawley which appeared in the Phenological Report presented at our last meeting. He says: "Favoured by the rains in May, the crop of hay was everywhere a remarkably heavy one. Then followed a severe drought, which, as far as its influence on vegetation is concerned, may be said to have lasted without a break throughout the whole of England from the beginning of June until the middle of October. Consequently, during a great part of that period the grass in the pastures was dried up, while the yield of roots turned out a very scanty one. On the other hand, the dry season suited the cereals admirably, and especially the wheat, which produced a singularly abundant crop of grain and straw."[1] Later on we learn from the same source that "at the beginning of October, not only were all crops at a standstill, but the ground had become so dry and hard that there appeared no chance of sowing any corn before the winter set in."[2] A fortnight later, however, the desired change set in, so that the agricultural season of 1898-99 started under happier auspices than seemed at one time at all likely. Summing up the general conditions, it may be said that the prolonged dry weather was favourable for the wheat crop, which seems, by the way, to be able to stand almost any amount of heat and drought, but was prejudicial to the roots and pastures, as well as in a limited degree to flowers and vegetables.

The effect of the drought upon the water supply was severely felt in many rural districts, where the inhabitants are dependent upon what is obtainable from wells and springs. In many places it was necessary to send long distances to obtain the necessary supply, and it is, I believe, a fact that in some instances residents in the country were forced to fly to town in order to escape the serious inconvenience arising from the drought. In order to obtain, if possible, some idea as to the effect of the dry weather upon the metropolitan water supply, I addressed, some time ago, letters to the secretaries of the various companies, asking to what extent their own particular services had been affected. From the ready replies so courteously sent, and for which I hereby tender the most grateful acknowledgments, it would appear that in all cases in which the supply is derived from the Thames, little or no inconvenience was occasioned, some of the companies having a supply sufficient not only for their own needs, but also to enable them to render assistance to their less fortunate neighbours. The result is perhaps not surprising when we consider the extent of the area covered by the Thames catchment basin, and also the fact that in the western parts of that area the deficiency of rain was not nearly so great as it was in and around London. In the metropolis itself the total rainfall for the 18½ months ending with the middle of October 1898 was, as we have already

[1] *Quarterly Journal of the Royal Meteorological Society*, vol. xxv. p. 140.
[2] *Ibid.* vol. xxv. p. 139.

seen, only 66 per cent of the average; but at Cookham the proportion was 69 per cent, while at Oxford, and also at Cirencester, it was as high as 75 per cent. That the drought was not without effect is, however, clearly shown by some figures kindly furnished by the authorities of the Thames Conservancy. From these it would appear that in 1898 there was a steady diminution in the discharge of water over Teddington Weir, interrupted only by the heavy rains in May; the volume in February, March, and April, and again in September and October, being considerably less than half the average as calculated from the 15 years records 1883-97. In February, and also in September, the proportion of the average discharge was very little over 40 per cent. The daily flow appears to have been at its minimum on September 13, when the number of gallons of water discharged was only 42 millions, a second minimum being, however, reached on the 20th of the same month, when the flow amounted to 48 million gallons; these amounts being, I am informed, the smallest ever recorded. During the 9 years ending 1891 the minimum daily volume of discharge (on August 14, 1887) was 154 millions of gallons, or from three to four times as great as that registered on two occasions in September, and considerably greater than on any day between August 21 and September 30 last.

The causes leading to a partial failure of the water supply in the east end of London suggest questions which are beyond our province to discuss. It is, however, only fair to remark that the area through which the river Lea flows is comparatively limited, and that it was exposed to a drought of more general severity than that prevailing over the Thames basin. Westward, the proportion of rain increased, as we have already said, from 66 per cent in London to 75 per cent at Oxford. Northward, it actually diminished, the proportion at Rothamsted being 64 per cent, and at Enfield 63 per cent. As a result of this, it appears that while at Teddington Weir the monthly flow of the Thames was never as low as 40 per cent of the average, at Field's Weir, a little below Ware, the flow of the Lea was in February 1898 as low as 29 per cent, and in November as low as 26 per cent. With regard to other sources from which the metropolitan water supply is derived, the only item of information we have been able to gather was from the Secretary to the Kent Company, who stated that after July in last year one of their most powerful springs at Orpington, at the head of the Cray, ceased to flow, the water failing to reappear, I believe, until early this year. The rainfall of the past winter has been in excess of the average, but in the south-eastern parts of England the excess has not been at all large, and for the whole of the past two years there has been, as our diagram showed, a considerable deficiency.

Postscript.

In compliance with a suggestion made in the Discussion by Mr. Mawley, I give a diagram (Fig. 24) showing for each of the 58 years 1841-98 the rainfall experienced at Greenwich during the summer and winter halves of the year; the summer half including the six months April to September, and the winter half the six months October to March. The average for the 50 years 1841-90 shows that in the

summer the total rainfall is about an inch greater than in the winter, the figures being respectively 12·75 ins. and 11·79 ins. In the diagram the average rainfall is shown by the dotted horizontal lines, so that the departure from the normal can in each case be readily seen.

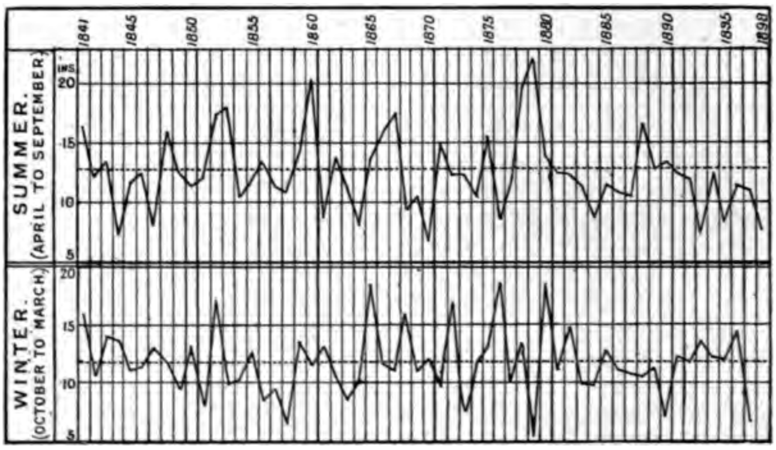

FIG. 24.—Summer and Winter Rainfall at Greenwich.

The curve for the summer months gives a maximum of 22·0 ins. in 1879, and secondary maxima of 20·3 ins. in 1860 and 17·9 ins. in 1853. The smallest summer rainfall occurred in 1870, when the total was only 6·8 ins., next to which came 1844 and 1893 with 7·3 ins. The most striking feature perhaps in the summer curve is the marked tendency for a deficiency in recent years. During the past 18 years there were only 3 with an aggregate summer rainfall equal to the average, and these were all consecutive, viz. between 1888 and 1890. In 4 of the remaining 15, viz. 1881, 1882, 1892, and 1894, the deficiency was slight, but in most of the other 11 it was considerable. At no other time in the past 58 years was the deficiency in the summer rainfall so frequent as in this 18-year period.

The curve for the winter months gives a smaller range than in the summer time. The maximum winter rainfall occurred with very close approximation, if not actually, in three different years. The actual maximum was in 1876-77 and in 1880-81, in each of which seasons the fall amounted to 18·7 ins., but in 1865-66 it was as much as 18·5 ins. The smallest winter rainfall occurred in 1879-80, when the total amount was only 5·5 ins., next to which came 1858-59 with 6·7 ins., and 1897-98 with 6·9 ins. The variability of the winter rainfall in the decade 1871-80 is very striking, the period including the two principal maxima and the two principal minima recorded during the whole 58 years. Since then the variations have been comparatively small. During the past 16 years the winter rainfall has been eight times in excess of the average, but in only three of these has the excess been at all large. In the remaining 10 years there was one with an average fall, and 4 with only a small deficiency. The other 5 showed a considerable deficit, the largest of all being in the season of 1897-98.

There is no evidence either in the summer or winter curve of any periodicity of rainfall, the chief tendency being for an excess in the 20 years 1861-80. The period, though the longest for which reliable records are available, is in all probability too short to yield any proof as to the existence or otherwise of large secular changes.

DISCUSSION.

The President (Mr. F. C. Bayard) said the thanks of the Society were due to Mr. Brodie for the interesting paper which he had prepared at the request of the Council at very short notice. The illustrations showed the salient facts very clearly. The engineer of the Sutton District Water Company had informed him (the President) that the water in the Company's wells was 3 ft. 5 ins. higher on February 28 of this year than on the corresponding date of last year, this instance showing the variation in the flow of underground water in chalky districts.

Mr. J. Hopkinson did not think the drought was as exceptional as was popularly supposed. He was under the impression that there was a drought about 1855 which would prove quite the equal of that under discussion. It was true that there had been a succession of dry years, but it was equally true that these years of drought had been preceded by a similar series of wet ones. To both of these periods there had been exceptions. Taking years beginning with April and ending with March, those of 1892 and 1897 (in the dry series of years) were wet. In the former year (1892), so much so, that the river Bourne commenced to flow after a quiet of twelve years. Taking 4 periods from 1875 to last year, the drought discussed by Mr. Brodie did not appear to be so extremely low. Thus :—

1875-81 = 90 per cent above the average.
1881-87 = 4 " " " " "
1887-93 = 47 " " below " "
1893-98 = 4 " " " " "

Taking the winter months only of these last two periods, that of 1887-93 was 8 per cent below the average, while the period 1893-98 represented 3 per cent above the average. The Chadwell spring had failed for the first time last year, it ceasing to flow about the end of July, recommencing December 1, and was now (March 15) flowing at about half the average. The river Ver was beginning to fail now after the excessive rain, which showed that the average was not yet made up. There was now no great deficit in the river Lea, and the Colne was about the average, but streams flowing on a chalk bed were very slow.

Mr. E. D. Archibald remarked that it would be interesting to see how far this period of drought would accord with Brückner's cycle. So far as he could recollect, the present was a generally warm and dry period which would end in about 1904 if the law held true for the 35-year cycle. In long periods there must always be irregularities, as shown in the present paper. The whole subject had an important bearing on the questions of agriculture and water supply. A long drought would probably affect the springs more than the surface water. The way the rainfall fringed off to the region of high barometer and greatest drought was very similar to what took place in Indian droughts, where the greatest drought occurred in the driest areas, and gradually diminished in intensity as the border of the rainy zone was reached.

Mr. G. J. Symons had hoped to hear the drought discussed with reference

to the general conditions of weather prevailing during the period. His own opinion was that these dry periods were due to displacements of areas of high pressure which caused depressions to take unusual courses. The drought was certainly more intense in areas of small average rainfall, but in this and other droughts he thought that that coincidence was secondary, and that there was an oscillation or displacement of the distribution of rainfall over the country. For instance, when the south and eastern districts of England were experiencing drought, the opposite condition was often prevalent in the north-west of Scotland, and *vice versa*. With reference to Mr. Hopkinson's remark respecting an earlier drought, the years 1856-58 were certainly very dry—so dry that Mr. Glaisher expressed a doubt if the average would ever be made up again. The total deficit of the five years ending with 1858 was nearly equivalent to a year's fall, and he thought it probable that in some respects it equalled the drought under discussion. With regard to underground water, this was a question of the percolation of the winter rainfall. He did not think London had suffered so intensely from the drought as parts of Kent and Essex. He thought that if one went into the details of the rainfall in the areas of greatest intensity, it would be found that there were within them very small areas where exaggerated intensity prevailed.

Dr. R. H. Scott remarked that with regard to intensity of drought, both that of 1856-58 and that which Mr. Brodie had discussed faded into insignificance beside that which was brought out by the diagram of 156 years (1726-1882) rainfall in these islands which Mr. Symons had published in *British Rainfall* for 1882. This was shown to extend from 1728 to 1767, and for these 39 years scarcely an individual year reached the average. He would ask Mr. Symons if he had yet seen occasion to modify this diagram?

He had placed recently in the Society's possession a continuation of the Rothamsted observations on percolation, which were only waiting for some one with the time at his disposal to work them up. The publication of the earlier position of these results had taken place in *Proceedings of the Institution of Civil Engineers*, vol. xlv. p. 61.

Mr. G. J. Symons, with reference to the diagram mentioned by Dr. Scott, said that he had in *British Rainfall*, 1896, mentioned that he had detected a misprint of 9 ins. in the *Philosophical Transactions*, which "will alter all the early part of the curve." He had hoped before now to have published revised values, but up till now had not had time for so doing.

Mr. E. Mawley said that he was glad to gather from the remarks of previous speakers that it was now generally recognised that, except from a purely meteorological point of view, there was little value in knowing how much or how little rain had fallen in any given year or number of months. The fact was that the rainfall year naturally divided itself into two distinct halves. In the first six months, which began with October and ended with March, nearly the whole of the rain deposited found its way into the springs, whereas, during the rest of the year, nearly the whole of it was either taken up by vegetation or evaporated. There was this further difference between the two seasons, in that the effect of the summer rainfall was only temporary, whereas, during the winter half of the year, the results must be, to a great extent, cumulative. For instance, last year he was asked by the Chairman of the Berkhamsted Water Company to supply him with the monthly rainfall returns for the previous 5 years, with a view to ascertain the cause of the deficient underground water supply then existing. Dividing the 5 years in question into their winter and summer halves, he was surprised to find that, although the summers had been all more or less dry, in 3 out of the 5 winters the rainfall had been in excess of the average, and that the total deficit for that six months in the 5 years only amounted to 0·81 in. However, by going back 15 years from the present time and comparing the

total rainfall at Berkhamsted with the average for the past 42 years, it will at once be seen what a very dry period that must have been.

In the 5 winters ending with that of 1898-99 the rainfall was 2·89 ins. below average.
In the 10 winters ending with that of 1898-99 the rainfall was 9·24 ins. below average.
In the 15 winters ending with that of 1898-99 the rainfall was 10·49 ins. below average.

The dryness of the summers during the same 15 years is still more pronounced.

In the 5 summers ending with that of 1898 the rainfall was 13·71 ins. below average.
In the 10 summers ending with that of 1898 the rainfall was 22·85 ins. below average.
In the 15 summers ending with that of 1898 the rainfall was 37·30 ins. below average.

Mr. W. B. Tripp said that, with reference to the failure of the Chadwell spring, as cited by Mr. Hopkinson, a newspaper appeared to state that the probable cause of the failure was the deeper sinking of a well at Haileybury.

Mr. R. Inwards thought the paper would be well supplemented by some observations on the effects of the dry period as regards health and disease, and it would be interesting to know how far the same conditions of dryness extended over the Continent.

Mr. J. E. Clark remarked on the entire omission of the Lake District from the paper. The Caterham Valley Bourne, near Croydon, like that in Hertfordshire, had flowed in the early spring of 1897, the previous occasion of its having done so being in 1887. He had seen a photograph of the Ure in Yorkshire, in the August of that same year (1887), in which a boy was standing astride the whole flow of the river at the Aysgarth Falls. This formed a marked contrast to a photograph obtained in the August of last year when the highest summer flood in living memory prevailed.

Mr. F. J. Brodie, in reply, said that undoubtedly the drought mentioned by Mr. Hopkinson, which lasted from November 1853 to March 1856, was both prolonged and severe, the rainfall being below the average in no fewer than 23 of the 29 months; but inasmuch as the proportion of rainfall for this period was 86 per cent, he did not think it was comparable in intensity with the dry period he had discussed in the paper. Mr. Hopkinson had also stated that the past succession of dry years had been preceded by a series of years of a wet character, which circumstance he (Mr. Brodie) thought was good ground for gratification, seeing that otherwise the results would probably have been much more disastrous. With regard to Mr. Archibald's suggestion, that the results in the paper should be compared with Brückner's cycle, he (Mr. Brodie) did not think there was any connection between them, as, whatever the foundation of the cycle, its effects could not be such as would cause deficiency in one part of the kingdom and an excess in another. He had not taken the question of atmospheric pressure into consideration at all in the compilation of the paper, for the simple reason that it would have doubled the time and labour expended upon it. He believed the conditions were generally anticyclonic, the depressions passing away to the northward and north-westward, which would in part explain the general excess of rain in Ireland and the north-western parts of Great Britain. Mr. Symons had given it as his opinion that the absolutely driest part of the country was Kent. As it happened, the lowest figures he had in his possession were for a

station in Kent, viz. Dungeness, but as some doubt attached to the average for that station, he had refrained from quoting them. The figures in the table showed that the total rainfall at Dungeness for the 18 months was nearly 5 ins. less than at any other station. With regard to the question of rainfall in the Lake District during the drought, the percentage was shown on the map, but he was not aware of any floods taking place in that neighbourhood until after the breaking up of the drought.

Mr. W. B. Tripp, in a note to the Secretary, remarked that as inquiries had been made in the discussion as to whether the drought described in the paper agreed with the cycles of Dr. Brückner, he had taken considerable interest in the question as to whether more precipitation takes place on the surface of the earth in some years or groups of years than in others, and he considered that these droughts were such as might be reasonably expected from the curves of Dr. Brückner, which he had seen, and from those made by himself, which he had sent to the Royal Meteorological Society in February 1890; from which latter it appeared that in Europe and some adjacent regions, where the averages were more complete than in other parts of the globe, at the 29 stations represented in those regions there was a period of comparatively high average rainfall about 1838-39, succeeded roughly in the "fifties" by the notable drought also referred to in the discussion, these again being succeeded by the comparatively high average rainfall of the "seventies"—again speaking roughly—culminating in Europe in 1872, somewhat similar manifestations being also exhibited, in his opinion, by the curve of sunspots, and by the curves or average of rainfall in other parts of the globe—the dates, however, vary somewhat in different parts.

Some of the principal results of such inquiries are, in Mr. Tripp's opinion, that series of years of high average rainfall and drought, with their attendant results, succeed one another alternately in more or less similar periods.

With regard to the objection raised in the discussion that some parts of England were wet while others were dry, this phenomenon is, of course, not uncommon, but it does not appear to entirely destroy—although it modifies—the extremes of the exhibition of the alternate periods above referred to in the average of a number of stations extending over a considerable area, as in the case of the curves of Dr. Brückner or those of Mr. Tripp above referred to, in which the most persistent of the wettest and driest periods come out when combined in the resultant average in curves. It is true that as the number of stations and the area over which they are scattered is increased the flatter and smoother the curves appear to become, but it remains to be proved whether, if the whole surface of the globe could be represented by rainfall stations equally distributed, the resultant lines would be quite flat from year to year and from period to period—in other words, whether the average rainfall of the globe is equal from year to year and from period to period. As far as Mr. Tripp has been able to observe, it does not appear to be so.

CLIMATE OF JERSEY.

By the Rev. H. W. YORKE, M.A.

[Read March 15, 1899.]

HAVING resided in Jersey for the last twenty years, and during that period been directly or indirectly interested in various meteorological observations, I have thought that a paper, however incomplete, on the climate of this island might be of some interest to the Fellows of the Royal Meteorological Society, especially since, so far as I am aware, no such paper has been read before.

For the purpose of this paper I have supplemented my personal observations by carefully comparing the MS. records of Captain Childers, St. Helier, 1844-60; Dr. King, St. Aubin, 1850-54; Judge Langlois, Millbrook, 1864-77; and Mr. J. E. Vibert, M.A., St. Aubin, 1874-86.

The situation and geological formation of the island, together with the action of the tides, have such a local effect upon the general character of the weather that, without considering these influences, it would be impossible to understand why the climate here is so abnormal.

Situation.—The island is situated in the Bay of St. Malo, off the north-west coast of France, in lat. 49° 15′ N. and long. 2° 10′ W. Its distance from the coast of France on the north is 30 miles, north-east 15 miles, south 32 miles, south-west 40 miles. On the north-west, at a distance of 18 miles, are the islands of Sark and Guernsey, also a reef called "the Douvres"; whilst to the south, at a distance of 15 miles, is another extensive reef called "the Minquiers." Consequently, except due west, it is more or less sheltered on all sides.

The shape of the island is roughly a rhomboid, of which the north and south sides are the longest, 11 miles each, and the west and east 5½ each, the north-west point being the most northern, the total area being about 45 square miles.

The population is 55,000, or about 1200 to the square mile.

The general slope of the land surface is from north-west to south-east, and consists of a plateau, intersected by nearly parallel valleys, sloping from north to south, narrow and deep, which with their various offsets give great variety to the altitude, slope, and drainage of different situations. Owing to the formation of these valleys, nearly the whole of the drainage of the land finds its way to the south and south-east coasts, on which we therefore find the most extensive low-lying marshy land, varying up to 1 mile in width in St. Clement's Bay.

The greatest altitude of the plateau on the north is 480 feet, and on the south-east 175 feet.

Tides.—The rise of the equinoctial spring tides on the south coast of Jersey is 42½ feet. The ordinary spring tides vary from 33 to 41 feet, and when the wind is North-west to South-west the ebb is very sluggish, causing a vast amount of water to remain near the island, and the following tide to be often 2 feet too high, with a marked increase of temperature. With the wind North-east to South-east the ebb is rapid, causing low tide to be 2 feet too low, with a marked decrease of temperature.

The mean annual temperature of the sea-water near shore is 54° (or 2° above the mean air temperature), which, owing to the vast amount of

ater passing the island between tide and tide, has, without a doubt, arked influence upon the climate, especially during winter and summer.

At "the Minquiers," 15 miles south of the island, the rise at uinoctial spring tides is 47 feet. At St. Malo, 30 miles south, at the ttom of the bay, the rise is 47½ feet; whilst at Guernsey, 18 miles rth-west, the rise is only 33 feet; and at Alderney, 28 miles north, ly 20 feet. The other tides vary in a corresponding ratio. The uble tide on the English coast, between Poole and Portsmouth, seems me to be caused by the ebb from this bay. It would be interesting to ace whether the North-west wind which causes the ebb here to be ggish also causes the flood of the second tide on the south coast of gland to be too low.

Barometrical Pressure.—The mean barometrical pressure in Jersey is ·977 ins. It is remarkable that we seldom experience the full force gales, the force being registered here as 5-7, when within a 150 mile dius from 7-9 is registered.

Clouds.—The amount of cloud seems greatest at night. Thunder-orms passing directly over the island are rare. Nearly all seem to be tracted by the high land on the coast of France.

Rain.—Of the annual amount, 34 ins., by far the greater part falls tween 6 p.m. and 6 a.m., consequently the apparent rainfall is not eat, and, coupled with the fact that the soil is very porous, it causes t slight inconvenience.

Sunshine.—The amount of sunshine registered here—averaging for 15 ars 1930 hours—is a proof of the observed fact of the absence of oud and rain during the earlier part of the day.

The above average, 1930 hours, is in reality too low, owing to some the evening sunlight having been lost from 1881-86, and of the orning sunlight from 1887-88, owing to the positions of the recorder. nce 1888 the average, I believe, has been over 1980 hours. The ightest period of the day is from 10 a.m. to 3 p.m. The brightest hour from 12 noon to 1 p.m.

Taking the average for 15 years, 1930 hours, I find it is 2 per cent possible duration more than at Guernsey, or nearly 9 minutes per day, d 5 per cent more than the sunniest place on the south coast of gland, or 29 minutes per day.

Humidity.—The relative humidity of the air is high, averaging 82 r cent, which causes the extremes of temperature to appear to the nses greater than they are in reality. This also at times causes a "chilly" eling in the air just after sunset, and an apparent rise in the tempera-re some two hours afterwards, which the thermometer readings do not dicate. On the south and south-east coasts mirage is often seen, pecially between the hours of 2 and 6 p.m.

Produce of the Land.—Being closely allied to an account of the climate this island, its produce, both vegetable and animal, must always be of terest.

As regards vegetation, Jersey, owing to its mean temperature being 2°, and its greatest extremes lasting but a very few days,—in some years urs only,—is capable of producing vegetable growth practically all the r round. Consequently, two crops are always possible, and generally ee, causing land to be let at from £12 to £18 per acre per annum.

The chief crop, the potato, planted early in February, is dug during May and June, yielding about £450,000 on export, being over £16 on an average for every acre of the whole surface of the island, or £45 for each acre planted.

The Lilac and Hawthorn are generally in flower during the first week of May. Wheat is in ear second week of June, in flower the third week, and the harvest commences at the end of July or first week in August. As regards the "Cattle," for which the island is renowned, the absence of tuberculosis is very striking. This, in a great measure, is no doubt due to the fact that no foreign cattle are allowed to be landed, except for immediate slaughter on the quay. Yet, indirectly, it is a proof that the climate of this island is undoubtedly favourable to the cure of consumption and allied diseases, especially in the earlier stages.

I have been unable to obtain exact statistics of the annual death-rate from consumption, owing to the careless registering, but one of the leading medical authorities assures me that this is remarkably low.

The total death-rate of the island is not as low as it ought to be—since the infant mortality is far too high in St. Helier, which contains about half the population of the island.

The cause of the high death-rate of infants in St. Helier is the non-sanitary condition of several of its streets and houses, part of the town being built on an undrained marsh, and over an old brook, which is used as a sewer, though there is no doubt that improper feeding is also to a great extent responsible.

The death-rate of the island—excluding St. Helier—is extremely low, and a great number of the people in the country live to the age of 90 or more, often without any loss of their faculties—even ages of 100 being by no means rare.

The average death-rate (1894-98) is for the Island 18·3 per 1000—for country parishes 15·6.

Notes on Weather in Jersey.

YEARLY MEANS.

Barometer	29·977 ins.
Shade temperature	52°
,, ,, mean of maxima	57°
,, ,, mean of minima	47°
Sun maxima	100°
Grass minima	43°
Coldest month	42° January
Warmest month	63° August
Sea water	54° (near shore)
,, December	40° ,,
,, August	60° ,,
Frost (*i.e.* on which *minimum* shade temperature *may* be 32° or below)	13 days
Frost on grass	49 days
Hail or snow (generally hail or "graupel")	30 days
Wind (0-12)	2·7
Cloud (0-10)	6·5
Sunshine	1930 hours
Rain	34 inches
Rainy days	190
Estimated hours of rain	775
Heavy dews	90 days
Fog or mist	30 days
Humidity	82 per cent
Prevailing winds	S.W. and N.E.
Lightning and thunder	15 times

I append the following Abstract of Observations taken by Mr. J. E. Vibert, M.A., at St. Aubins, Jersey (1875-79):—

Months.	Barometer.	Temperature.				Rain.	Relative Humidity.
		Mean in Shade.	Max. in Sun.	Min. on Grass.	Sea.		
	ins.	°	°	°	°	ins.	%
January	30·096	43·1	69·9	35·7	45·2	3·831	86
February	29·992	43·6	78·7	36·3	45·1	2·926	88
March	29·976	44·4	93·1	35·3	46·3	2·378	81
April	29·875	48·7	107·9	38·9	49·9	2·525	82
May	30·017	52·8	116·6	42·8	52·8	1·783	76
June	30·005	59·3	121·3	49·4	57·4	1·785	80
July	30·062	62·3	122·8	53·1	60·5	1·743	80
August	29·976	63·7	122·4	54·1	63·5	2·463	82
September	30·041	60·5	116·2	50·0	61·8	3·260	79
October	29·981	55·2	100·2	45·4	57·9	3·330	79
November	29·933	47·4	83·2	38·2	51·4	4·905	80
December	30·007	42·9	75·4	33·7	45·6	3·298	83
Year	29·997	52·0	100·6	42·6	53·1	34·227	81

DISCUSSION.

The President (Mr. F. C. Bayard) said that the Society were indebted to Mr. Yorke for what he believed was the first description of the climate of Jersey they had ever received. He thought that the difference in height attained by the tide at places so short a distance apart was rather remarkable. The relative humidity of the island, viz. 82 per cent, appeared high.

Mr. J. Hopkinson remarked on the omission of the time of observation. If it was 9 a.m., he did not consider the percentage of relative humidity a high one, the figures agreeing with those of an inland station like St. Albans.

Dr. R. H. Scott did not think the heights attained by the tide exceptional, as at St. Malo the rise of the equinoctial spring tides is 47½ feet, while at Chepstow on the Severn it is not very rarely 50 feet.

Mr. J. F. Curtis pointed out that a table of monthly results would add greatly to the value of the paper, and suggested that Mr. Yorke should be asked to supply, if possible, such a statement to be printed in the *Quarterly Journal*.

Mr. R. H. Curtis suggested that, as no less than five different series of observations had been mentioned as having been more or less used in compiling the paper, it would be an advantage to state whether the mean values given at the close had been derived from a combination of all the series, or only from some particular series, and in the latter case, which. He thought it very probable that at least some of the figures came exclusively from observations made at St. Aubin's, and that probably to that fact was due the statement as to the low wind-forces experienced in Jersey. St. Aubin's was a particularly sheltered spot, nestling under high, steep banks which completely cut off any winds blowing from South, through West, to about North-east; the town being situated in the angle formed where the cliff turns to the southward after running from east to west. He thought it very probable that had the wind observations been made at a fully exposed spot such as La Corbière, the force would have been found to be somewhat higher.

Mr. E. D. Archibald agreed with Mr. R. H. Curtis as to the sheltered situation of St. Aubin's. Anemometrical observations in Jersey should be taken on the central plateau, or on a tower such as used by Père Dechevrens at the Observatoire St. Louis, and illustrated by Mr. Marriott's slide; otherwise, round the coasts, however good the apparent exposure, there was always a danger that the air would be deflected upwards by the plateau, and thus reduce the amount of wind registered by an anemometer below on the coastal plain.

REPORT OF THE COUNCIL

FOR THE YEAR 1898.

THE Council, in presenting their Report for the past year, congratulate the Society upon its present satisfactory position, and also upon the recent acquisition of New Offices well suited to its requirements. There has been a decrease in the number of Fellows paying annual subscriptions, but, on the other hand, an increase in the number of Life Fellows. The total number of Fellows on the list is now 564.

It is with deep regret they have to record the death, at the advanced age of ninety-seven, of their esteemed Treasurer, Mr. Henry Perigal, F.R.A.S. Although not actually one of the original founders of the British (now the Royal) Meteorological Society, Mr. Perigal joined the Society within a few months of its establishment in 1850. He was elected on the Council in the following year, and appointed Treasurer in 1853, and he held that office until his death on June 6, 1898—a period of forty-five years.

The Council also regret to record the death at the age of ninety-four of Mr. John Hippisley, F.R.S., who joined the Society a month after its foundation.

Of those who were either founders (marked *), or were elected in the first year (1850), we have still with us the following Fellows:—

*J. Glaisher, F.R.S.	C. L. Prince, F.R.A.S.
*W. Johnson, F.R.A.S.	*Rev. Canon Slatter, F.R.A.S.
*E. J. Lowe, F.R.S.	

To fill the vacancy caused by the death of Mr. Perigal, the Council, under Bye-law 5, appointed on June 15 one of the Past-Presidents, Dr. C. Theodore Williams, as their Treasurer, to hold office until the present Annual Meeting.

Committees.—The Council have been materially assisted by several Committees, which were constituted as follows:—

EDITING COMMITTEE.—The President, Mr. Inwards, Rear-Admiral Maclear, and Dr. Scott.

GENERAL PURPOSES COMMITTEE.—The President, three Secretaries, Treasurer, Messrs. Ellis, Inwards, and Dr. Theodore Williams.

HOUSE ACCOMMODATION COMMITTEE.—The President, three Secretaries, Messrs. Heberden, Inwards, Latham, and Dr. Theodore Williams.

WIND FORCE COMMITTEE.—The President, Secretaries, Messrs. Chatterton, R. H. Curtis, Dines, C. Harding, Munro, Dr. Scott, and Captain Wilson-Barker.

The New Offices of the Society.—Towards the end of July notice was served on the Society by H.M.'s Office of Works to treat for the acquisition of the interest of the Society in No. 22 Great George Street, in pursuance of the powers contained in the "Public Offices (Westminster) Site Act, 1896." On receipt of this notice, Messrs. Fladgate and Co., Solicitors, and Mr. Penfold, Surveyor, were instructed to represent the Society in its negotiations with the Government. The Council trust that, as the result of these negotiations, adequate compensation will be

awarded to the Society for the inconvenience and expense to which it will be put in the removal from the present rooms to the New Offices.

The House Accommodation Committee, after inspecting several sets of rooms in the neighbourhood of their present offices, decided to recommend to the Council a suite of rooms on the second floor at Prince's Mansions, No. 70 Victoria Street. Their recommendation having received the approval of the Council, arrangements were at once made for taking the rooms in question on lease for twenty-one years from December 25, 1898, at a rental of £200 per annum—being the same rent as paid for the rooms in Great George Street.

The Council regret being obliged to remove so far from Great George Street, where their Meetings have been held for so long a time; and they fear that the inconvenience this entails will only be partially compensated for by the fact that the new rooms are large and lofty, and consequently better able to accommodate the rapidly increasing library.

Lecture.—Instead of the usual Exhibition of Instruments in March, a Lecture was delivered by Mr. A. W. Clayden, M.A., F.R.A.S., "On Photographing Meteorological Phenomena." This was illustrated by numerous photographs, and there was a large attendance of Fellows and their friends.

Meetings.—The rooms of the Institution of Civil Engineers, at which the Society has for so many years been so hospitably received, were not available for the meetings in May and June, and the Society, by the kind permission of the Royal Astronomical Society, met in those months in the rooms of that Society at Burlington House. These afternoon meetings, as in the previous year, appear to have been appreciated by many of the Fellows residing at a distance from London, who are usually unable to attend those held in the evening.

Quarterly Journal.—The following papers of interest, amongst others, have appeared in this publication:—The Presidential Address by Mr. Mawley on Weather Influences on Farm and Garden Crops; Anticyclonic Systems and their Movements, by Major Rawson; The Frequency of Rainy Days in the British Islands, by Dr. Scott; and The Exploration of Free Air by means of Kites, by Mr. A. L. Rotch.

Meteorological Record.—The issue of this publication having fallen somewhat in arrear, an effort has been made to bring it more up to date. As the result of this effort five numbers of the Record have been distributed to the Fellows during the year, the last issue bringing the observations up to the end of September.

Wind Force Experiments.—On June 17, at the invitation of the President and Captain Wilson-Barker, the Wind Force Committee visited H.M.S. *Worcester* off Greenhithe, in order to inspect the various anemometers which had been constructed by Mr. Munro, and erected for experimental purposes in 1896 at different heights above the deck of that ship under the direction of Mr. Dines and Captain Wilson-Barker. The Committee expressed their approval of the arrangements. The Report on these experiments was read at the November meeting, and will be found in the *Journal.*

Research Fund.—No contribution has been received for this Fund during the year. The first claim upon it will be the cost of the anemometers erected on H.M.S. *Worcester*, as already mentioned. Further

contributions to this fund are invited in order that other investigations may be undertaken by the Society.

Medal to Cadets on H.M.S. "Worcester."—In order to encourage the study of Meteorology, the Council have decided to give a silver medal for the best essay by one of the Cadets of the Thames Nautical Training College, H.M.S. *Worcester*, on some meteorological subject, to be selected each year by the officers of the two Institutions. Our President has very kindly promised to present the die for this medal to the Society.

Stations.—The following are the only changes made in the Stations of the Society :—Observations have been accepted from Grayshott, Hants; Llanbedr, Merionethshire; and Hoylake, Cheshire: while those at Driffield, Yorkshire; and Bude, Cornwall, have been discontinued.

Inspection of Stations.—All the Stations south of latitude 54° N., and west of longitude 2° W., as well as a few others elsewhere, were inspected and found on the whole in a satisfactory condition. Mr. Marriott's Report is given in Appendix II. (p. 214).

Phenological Report.—This Annual Report was as usual prepared by Mr. Mawley and read at the February meeting. It was the seventh report of the new series, in which the observations have been discussed on the same uniform plan.

Sanitary Congress.—In the early part of the year the Council appointed the President and Mr. Dickson, as delegates from the Society, to attend the Sanitary Congress held at Birmingham in September.

Library.—Considerable additions, by presentation and purchase, have been made to the Library, as well as to the collection of Photographs and Lantern Slides. A list of these purchases and presentations will be found in Appendices IV. and V. (pp. 225, 226).

Photographs.—At the request of the Royal Photographic Society, some Meteorological Photographs were lent for exhibition at the International Photographic Exhibition of that Society, which was held at the Crystal Palace in April.

Fellows.—The changes in the number of Fellows are exhibited in the following table, which shows a decrease of nineteen during the year :—

Fellows.	Annual.	Life.	Honorary.	Total.
1897, December 31	422	145	16	583
Since elected . . .	+26	+4	+2	+32
Since compounded .	−1	+1	...	0
Reinstated	+1	...	...	+1
Deceased	−10	−4	...	−14
Retired	−26	...	...	−26
Struck off	−7	...	...	−7
Lapsed	−5	...	...	−5
1898, December 31	400	146	18	564

For Continuation of Report of the Council, see page 214.

APPENDIX

STATEMENT OF RECEIPTS AND EXPENDITURE

RECEIPTS.

Balance from 1897				£280	15	0
Subscriptions for 1898	£667	1	0			
Do. for former years	53	19	0			
Do. paid in advance	16	0	0			
Life Compositions	105	0	0			
Entrance Fees	26	0	0			
				868	0	0
Meteorological Office—Copies of Returns	£108	7	2			
Do. Grant towards Inspection Expenses	25	0	0			
				133	7	2
Dividend on Stock (including £40 : 18 : 2 from the New Premises Fund)				130	6	3
Sale of Publications, &c.				50	15	6
				£1463	3	11

I.

FOR THE YEAR ENDING DECEMBER 31, 1898.

EXPENDITURE.

Journal, &c.—		
Printing Nos. 105 to 108	£131 16 6	
Illustrations	51 19 4	
Authors' Copies	12 19 6	
Meteorological Record, Nos. 66-71	71 7 6	
Registrar-General's Reports	1 16 9	
		£269 19 7
Printing, &c.—		
General Printing	£22 1 6	
List of Fellows	9 12 6	
Stationery	10 14 10	
Books and Bookbinding	13 8 11	
		55 17 9
Office Expenses—		
Salaries	£455 4 5	
Rent and Housekeeper	200 0 0	
Repairs, Coals, &c.	18 8 8	
ostage	59 10 10	
etty Expenses	20 10 4	
efreshments at Meetings	14 14 11	
ecture	10 10 0	
		778 19 2
Observations—		
spection of Stations	£55 2 4	
bservers	9 2 0	
struments	2 17 8	
		67 2 0
Stock—		
urchase of £100 L. & N.-W. R. Stock, at 204⅞		206 3 6
		£1378 2 0
Balance—		
t Bank of England	£81 16 3	
In hands of Assistant-Secretary	3 5 8	
		85 1 11
		£1463 3 11

Examined and found correct,

FRED^C. GASTER, M. JACKSON, } *Auditors.*

January 11, 1899.

APPENDI

ASSETS AND LIABILIT

LIABILITIES.

To Subscriptions paid in advance	£16 0 0	
,, Rent for quarter ending December 25, 1898 . .	50 0 0	
		£ 66 (
,, Excess[1] of Assets over Liabilities		3402]
		£3468 1

1 This excess is exclusive of the value of the Library and Stock of Publications.

NEW PREMISES FU

Amount paid to the Society's Funds towards the rent of rooms at 22 Great George Street	£40 1[illegible]

RESEARCH FU

Amount invested in the purchase of £3 : 0 : 1, 2¾ per cent Consols .	£3 (

I.—Continued.

ON JANUARY 1, 1899.

ASSETS.

By Investment in Great Central Railway $4\frac{1}{2}$ per cent Debenture Stock, £800 at $153\frac{1}{2}$ xd . . .	£1228 0 0	
,, Investment in New South Wales 4 per cent Inscribed Stock, £654 : 18s. at $117\frac{1}{2}$	769 10 2	
,, Investment in London & North-Western Railway Consolidated Stock, £350 at $202\frac{1}{4}$	707 17 6	
,, Investment in $2\frac{1}{2}$ per cent Annuities, £231 : 11 : 9 at $104\frac{1}{8}$	241 2 10	
		£2946 10 6
,, Subscriptions unpaid, estimated at	£50 0 0	
,, Entrance Fees unpaid	6 0 0	
,, Interest due on Stock	51 18 4	
		107 18 4
,, Furniture, Fittings, &c.	£194 14 10	
,, Instruments	133 15 8	
		328 10 6
,, Cash at Bank of England	£81 16 3	
,, Cash in hands of the Assistant-Secretary . .	3 5 8	
		85 1 11
		£3468 1 3

DECEMBER 31, 1898.

Interest received on investment £40 18 2

Note.—The Society holds on account of this Fund £1209 : 4 : 10 South Australian $3\frac{1}{2}$ per cent Inscribed Stock.

DECEMBER 31, 1898.

Interest received on investment £3 6 3

Note.—The Society holds on account of this Fund £124 : 4 : 8, $2\frac{3}{4}$ per cent Consols.

Deaths.—The Council have to announce with much regret the deaths of the following Fellows:—

Joseph Gurney Barclay, F.R.A.S.	elected	March	19, 1862.
Hamar Alfred Bass, M.P.	"	Dec.	19, 1894.
William Belk, M.Inst.C.E.	"	March	19, 1890.
Duncan James Caddy, M.D., F.R.G.S.	"	Jan.	16, 1895.
John Edmund Chandler, F.R.G.S.	"	Jan.	15, 1896.
Jeremiah James Colman, J.P., D.L.	"	June	17, 1891.
Robert Foster.	"	Feb.	18, 1885.
Henry Gale, M.Inst.C.E., F.R.G.S.	"	Dec.	18, 1889.
John Hippisley, F.R.S., F.R.A.S.	"	May	7, 1850.
George James Lee, F.R.M.S.	"	Nov.	19, 1884.
Frank Mead, Assoc.M.Inst.C.E.	"	Dec.	18, 1889.
Henry Perigal, F.R.A.S., F.R.M.S.	"	June	4, 1850.
Sir Richard Quain, Bart., M.D., LL.D., F.R.S.	"	March	16, 1892.
James Rock.	"	Nov.	17, 1858.

APPENDIX II.

INSPECTION OF STATIONS, 1898.

All the stations west of 2° W. long. and south of 54° N. lat., as well as a few others, have been inspected, and were, with a few exceptions, found to be in a satisfactory condition.

The number of thermometers tested has been 163, 23 of which had altered since the previous examination; 17 rain-gauge measure-glasses have also been tested, 3 of which were not correctly divided.

I found that two maximum thermometers of Messrs. Negretti and Zambra's pattern had lost their power to retain the mercury at its highest point, and had practically become like ordinary thermometers.

I have noticed in a few instances that the mercury in the column of a Negretti and Zambra maximum thermometer is sometimes liable to become broken (probably owing to the presence of air), and to give too high a reading, especially if there should be any vibration of the screen. When this is the case, it is desirable that the thermometer should be inclined before being read, so that the detached portion of mercury may join the main column.

A maximum thermometer of Phillips's pattern was found to be reading 0°·9 too low. This seems to be very remarkable, as mercurial thermometers have a tendency to read too high with age, and not too low.

The records from Scarborough had not been satisfactory for some time, so I made a special visit to that station. I found that Mr. Ellerbeck, who is the Corporation Meteorologist, had practically left all the observing and office work to a lad, and exercised no supervision, but only took the Sunday readings; consequently the observations had not been properly made, nor had the readings been correctly entered up in the various books. After going fully into the matter with

Mr. Ellerbeck, he undertook for the future to carefully supervise and check all the observations and returns.

At Buxton I found that the observer was using an 8-inch measuring-glass for a 5-inch rain-gauge !! the 5-inch glass having been broken some months previously.

The information given by Mr. R. H. Curtis in his paper on "Sunshine Recorders and their Indications" has been of service in examining the sunshine recorders. At two stations, Penzance and Woolacombe, I found that the glass balls of the Campbell-Stokes recorders were defective; they weighed about 3 lbs. 14 oz., instead of only 3 lbs. These have since been returned to the makers, and exchanged for proper balls.

WM. MARRIOTT.

October 17, 1898.

NOTES ON THE STATIONS.

ABERYSTWITH, *July* 13.—There was no change in the zero of the thermometers. The observer, being a medical man, has great difficulty in taking the observations punctually.

ADDINGTON, *October* 3.—The former observer, Mr. Crane, left in July, when Mr. Prior took charge of the instruments. I found that he had not received any instruction, and was consequently not familiar with the method of observing. He had read the end of the spirit instead of the index in the minimum thermometer, so gave the temperature at the time of reading instead of the lowest since the last observation. He had, however, set the index each day. The muslin and cotton on the wet bulb were not working properly. I gave Mr. Prior full instruction in the method of observing, etc.

ASHBURTON, *August* 26.—There was no change in the thermometers. The thermometer screen required fresh posts. I recommended that the screen be moved to a spot near the rain-gauge in the field, and that the whole be surrounded by railings. In the present situation the air may possibly be heated a little by the sloping bank close to the screen.

BELMONT, HEREFORD, *July* 9.—I recommended a rearrangement of the thermometers in the screen, and also that four holes be made from the outer rim of the cylinder of the Glaisher rain-gauge to drain off the water, and so prevent any splashing when the funnel is taken off.

BLACKPOOL, *July* 20.—The minimum thermometer had 0°·5 of spirit up the tube. The thermometer screen required painting. The ball of the sunshine recorder was not quite in the centre of the frame. The Blackpool Tower cuts off a little of the sunshine in the winter, as the top of the Tower makes an angle of 13° in the south-east. Apparently the recorder is sometimes tampered with, as the cards have shown the sun to be shining at impossible times.

BOLTON, *July* 21.—I recommended that the enclosure containing the meteorological instruments should be re-turfed and the grass kept short. The trees, etc., may possibly cut off a little of the early and late sunshine, as those on the east make an angle of 7°, and those on the west an angle of 5°.

BUDE, *September* 2.—The muslin on the wet bulb was dirty, and had not been changed for a long time. The pipe was broken off the funnel of the rain-gauge. On taking off the funnel, I found some rain water in the can, although there had been no rain for several days past. I then ascertained that the gauge had not been looked at since August 28, and also that the observer only looked at

it when he thought there had been rain. I pointed out the necessity of strictly complying with the rule of the Society, which is that "the gauge must be examined daily at 9 a.m." (*Hints to Meteorological Observers*, 1897, p. 18).

BURGHILL, *July* 8.—On testing the thermometers, I found that the dry and wet had each gone up 0°·1, and that the minimum had gone down 0°·3. On examining the maximum thermometer, which was of Negretti and Zambra's pattern, I found that it was liable not to register properly, as the mercury ran back, and so caused the instrument to act as an ordinary thermometer. I gave instructions for a new maximum thermometer to be obtained forthwith. As the thermometer screen was liable to be shaken by the wind, I recommended that it be remounted on stouter posts. The grass minimum had 4°·5 of spirit detached from the column.

BUXTON, *July* 22.—The thermometer screen required painting. A 5-inch rain-gauge was in use, but I found that an 8-inch measuring-glass was being used with it without any allowance for difference as to size. The 5-inch measuring-glass had been broken in the earlier part of the year. I pointed out that the rain records under these circumstances were fallacious, and recommended that a new 5-inch measuring-glass be obtained forthwith. The barometer did not seem to be read very correctly. It appeared that the observations were not taken punctually at the regular observing hours.

CASTLE HILL, SOUTH MOLTON, *September* 7.—There was no change at this station. The instruments were clean and in good order.

CHELTENHAM, *July* 7.—As the trees near the rain-gauge have grown very much and subtend a considerable angle, I recommended that one of the gauges should be removed about 50 feet farther south into a more open situation. The grass minimum had some spirit up the tube. A Jordan sunshine recorder has been placed on the dome of the Pagoda in the Pittville Gardens. It is well exposed, but required to be securely fixed.

CHESTER, *July* 16.—I did not test the thermometers, as Mr. Mitchell said that they would all be sent to Kew shortly for re-verification. Mr. Mitchell has recently started four earth thermometers at 1 foot, 2 feet, 3 feet, and 4 feet.

CHURCHSTOKE, *July* 12.—The minimum had 1°·5 of spirit broken away from the column, and had been reading too low by that amount since March 25. The sunshine recorder was not in proper adjustment for time, nor was the ball quite in the centre of the frame.

COLWYN BAY, *July* 15.—The whole of the instruments have been moved to a railed-off enclosure on the northern side of a field, close to a row of shrubs and trees. The rain-gauge is consequently not satisfactorily exposed, nor do the two sunshine recorders get all the sunshine. If placed on the other side of the enclosure they would be better exposed, but not then perfectly. The ball of the Campbell-Stokes recorder is much larger and heavier than it should be, and it also has some peculiar lines inside. As the ball is larger than is proper for the frame, the time by the sun does not correspond with that on the card; and there is consequently a difference in the times and amounts of sunshine by the Campbell-Stokes and the Jordan sunshine recorders. The earth thermometers had thick pieces of rubber round the bottom, and these had swollen so much that they caused the sticks holding the thermometers to become jammed in the tube, so as not to go to the proper depths. The 4-foot thermometer stuck in the tube at about 2 feet.

CULLOMPTON, *August* 24.—This station was in good order.

DARWEN, *July* 21.—The instruments are placed in the Bold Venture Park, on ground sloping from west to east. The thermometers, rain-gauge, etc., are

placed in a circular railed-off enclosure. A little higher up is a structure something after the plan of the Fernley Observatory at Southport. In this is a large Fortin barometer, and a Richard barograph and thermograph. On the top is a Campbell-Stokes sunshine recorder, a Robinson anemometer, and a Dines sight-reading pressure-tube anemometer. The hills rise to an angle of 10° from south to north-west; Darwen is in the valley to the east. I recommended a re-arrangement of the thermometers in the screen.

FALMOUTH, *August* 30.—On testing the thermometers, it was found that the dry and wet had each gone up 0°·1, and that the maximum had gone up 0°·2. The thermometer screen had been moved to the north side of the lawn. As the mercury in the maximum (Phillips's pattern) had a tendency to run up the tube, I recommended that it be a little inclined.

GRAYSHOTT, *December* 16.—I visited this station on the above date, and selected a new site for the instruments. The ground slopes from north to south. The soil is sandy, and there is an abundance of fir trees. The height is 660 feet above sea-level. There is a valley and hill to the south-south-west. On testing the thermometers, it was found that the dry and wet had both gone up 0°·2.

GWERNYFED PARK, *July* 11.—On testing the thermometers, it was found that the minimum had gone down 0°·2. I gave the observer instructions as to the manipulation of the wet bulb in frost.

HARROGATE, *July* 25.—The observations at this station had fallen considerably into arrear. After conversation with Mr. Farrah, he agreed to see if arrangements could be made for the carrying on of the observations.

HAVERFORDWEST, *August* 20.—On comparing the thermometers, it was found that the dry and wet had each gone up 0°·2. Mr. Phillips has a very good Richard barograph with enlarged scale. The record by this instrument during the thunderstorm of August 18 was exceedingly interesting. Mr. Phillips, on December 31, will have completed 50 years' record of rainfall.

HOYLAKE, *July* 18.—The instruments are placed on a lawn at the back of the Urban Council Office, close to the railway station, and have a good exposure. The ground is quite flat from the sea to some 3 miles east. The soil is sandy. The Campbell-Stokes sunshine recorder is mounted on the ridge of the building. A ventilating shaft on the south-west makes an angle of 25°, which cuts off a little sunshine from October to March.

ILFRACOMBE, *September* 3.—On testing the thermometers, I found that the wet bulb had gone up 0°·2. As the thermometers in the old screen still remain in position, I found that the maximum during the summer had been 76°·3, which agrees very closely with 76°·2 in the new screen. On September 5 I found the maximum in the old screen to be 78°·0, and in the new screen 77°·8. These readings show that there is very little difference between the temperatures recorded in the two screens.

LLANBEDR, *July* 14.—This station is in Merionethshire, about 3 miles south of Harlech. The sea is a mile and a quarter distant to the west, the intervening land being flat. On the east, however, there are hills over 2000 feet within a distance of 5 miles. The instruments are placed in the kitchen garden, at the south side of the house. There are trees and hills to the south. Peas had been allowed to grow too near the rain-gauge. I requested that they be kept farther back.

LLANDUDNO, *July* 15.—The barometer had been moved from its former position to the porch of Dr. Nicol's house. The other instruments were as before. The sunshine recorder is mounted on the top of a lamp-post frame at

the western side of the town, and has a very good exposure. Dr. Nicol has presented all his meteorological instruments to the Town Council on condition that the observations are continued. Mr. Little, the Sanitary Inspector, is now the observer.

MALVERN, *July* 8.—The thermometer screen required to be strengthened and painted. As the rain-gauge was worn out, I recommended that a new one be obtained. On testing the rain-measuring glass, I found that it was ·01 in. too low from ·10 to ·50.

NEWQUAY, CORNWALL, *September* 1.—On testing the thermometers, I found that the dry and wet had both gone up 0°·2. As the field in which the thermometers are placed has been laid out for building purposes, it will be necessary shortly to remove the instruments to another place. The rain-gauge will also have to be moved from the kitchen garden in which it is now placed, as a chapel is to be erected on the site.

NORTHWICH, *July* 16.—On testing the thermometers, it was found that the dry had gone up 0°·2, and the wet 0°·1. The screen required painting. I gave the observer instructions as to the management of the wet bulb during frost, and also as to the measurement of snow.

OLD STREET, LONDON, *September* 15.—I found that the column of spirit in the minimum thermometer was broken up, and that the instrument was consequently out of order. I recommended that all the trees round the rain-gauge be cut back as much as possible.

PENZANCE, *August* 31.—On testing the thermometers, it was found that the dry and wet had both gone up 0°·2. The thermometer screen and rain-gauge had been moved at the beginning of June to a more open site in the Morrab Gardens. There is now more circulation of air round the instruments. The Campbell-Stokes recorder did not appear to be working satisfactorily; the burn on the card was too broad, and the early and late sunshine was apparently not recorded at all. I found the glass ball was defective, as it weighed 3 lbs. 13½ oz., instead of only 3 lbs. I recommended that the ball be returned to the makers and exchanged for a proper one.

PRINCETOWN, *August* 27.—This station was in good order.

ROSS, *July* 9.—The thermometer screen required painting. I recommended that some branches be cut off a tree to the south of the rain-gauge, and also that some plants be moved farther away.

ROUSDON, *August* 23.—On testing the thermometers, it was found that the grass minimum thermometer had gone down 1°, and that the 4-foot earth thermometer had gone up 0°·1. I recommended that the grass minimum should be placed on the grass, and not, as now, about 6 inches above it. The evaporation observations have been given up, as they have extended over 10 years, and as the exposure has become too confined, owing to the growth of trees. A tower has been erected to clear the trees and to give a free exposure for the sunshine recorder, the Dines and Robinson anemometers, and the Richard pluviograph.

RUMNEY, *August* 18.—The instruments are in a railed-off enclosure in a field on the site selected at my previous visit. The tube of the maximum thermometer had slipped down about a degree. This I readjusted and made secure.

SCARBOROUGH, *July* 25.—The instruments had been removed from the South Cliff to a new site in Alexandra Park, on the north side of the town, about a mile from the sea. The instruments are placed in a garden on sloping ground. The exposure is open all round. The sunshine recorder is mounted on the ridge of the roof. The instrument was not level, but as I could not unscrew it, or get a carpenter to help me, I could not adjust the instrument myself; but

I explained what was required to be done, and Mr. Ellerbeck promised to have it done properly. Mr. Ellerbeck is Borough Meteorologist, and has two sets of instruments, one set belonging to the Corporation and the other to himself. He apparently left all the observing and office work to a lad, and did no supervising, but only took the Sunday readings. The lad I saw was very intelligent, but the previous one must have been very careless. Mr. Ellerbeck had been very negligent in not taking any pains to see that the observations were properly made, and that they were carefully entered up in the various books and forms. I pointed out numerous cases where the readings on the monthly and weekly returns did not agree. Many of these were cases of gross carelessness, where the readings from either screen had been copied indiscriminately, or the corrections had been wrongly applied. Mr. Ellerbeck undertook to carefully supervise and check all the observations and returns for the future.

SHAFTESBURY, *September* 8.—Miss Wand left the Hospital in August, and the new matron, Miss Harris, has taken charge of the observations. I instructed Miss Harris in the use of the instruments and in the method of taking the observations. The column of spirit in the minimum thermometer had become broken a few days previously. This I speedily set right.

SIDMOUTH, *August* 24.—The Jordan sunshine recorder has been moved from the Knowle Hotel to Dr. Radford's grounds. The exposure is not very satisfactory, although it appears to be the best available.

SOUTHPORT, *July* 19.—The instruments in the Hesketh Park have been removed to another site at the foot of the knoll on which the Fernley screen stands. A Beckley self-recording rain-gauge has been obtained, but it was not working satisfactorily. A Dines self-recording pressure-tube anemometer, and also a self-recording direction anemometer, are at work at the Marshside Fog Bell station.

TORQUAY, *August* 25.—On testing the thermometers, it was found that the maximum had gone down 0°·9, and the minimum 0°·2. The index of the maximum was much too long, so I recommended that it be shortened by immersing the thermometer in a mixture of salt and ice. The Campbell-Stokes sunshine recorder has been discontinued, as Mr. Chandler believed it was not giving correct results. The Jordan recorder (twin pattern) has the box fitting as a cap, and not, as is usual, the cap fitting on to the box; so it was not possible to see the spot of light on the paper. The papers did not fit tightly, but were somewhat loose in the boxes; the time was therefore liable to be variable.

WAKEFIELD, *July* 26.—The index of the maximum was much too long, the air bubble apparently being liable to get into the bulb at about 40°. I recommended that the index be shortened by placing the thermometer in a mixture of ice and salt. The thermometer screen required cleaning and painting.

WESTON-SUPER-MARE, *August* 22.—I found that the maximum (Negretti and Zambra's pattern) was working as an ordinary thermometer, the contraction not being sufficient to keep up the mercury at its highest point. I requested that the thermometer be returned to the makers for repair. On testing the rain-measuring glass, I found it to be incorrectly graduated. A new post-office is being built close by the instruments. It is therefore desirable that they should be moved farther into the field.

WHITCHURCH, *August* 29.—At the end of 1897, Mr. Glyde moved his station from Rose Villa, Tavistock, to Statsford, Whitchurch, about 2½ miles south-east. This is on the edge of Whitchurch Moor, and is 5¼ miles west by south from Princetown. The instruments are placed in the kitchen garden. On testing the thermometers, it was found that the maximum had gone up 0°·2.

WOOLACOMBE, *September* 5.—The instruments were clean and in good order. The ball of the sunshine recorder was not in the centre of the frame. The trace was very broad in the middle of the day, but faint in the early morning and late evening. The ball weighed 3 lbs. 14 oz. As this was a defective ball, I requested that it be returned to the makers and exchanged for a proper one. The original glass ball was stolen soon after the instrument was put up, and this defective one had been obtained in place of it.

APPENDIX III.

OBITUARY NOTICES.

JAMES GURNEY BARCLAY, who was born in 1816, was the son of Robert and Elizabeth Barclay, in direct descent from Colonel Barclay (1610), who purchased the Urie Estate, and from his son Robert Barclay, author of the *Apology*. When J. G. Barclay was a boy, his father purchased, and went to live at, Knott's Green, Leyton, which has since been a family residence of the Barclays.

For more than fifty years, J. G. Barclay was a partner (in later years the head) of the well-known banking firm of Barclay, Bevan, and Co.; he retired from the firm on its amalgamation with a number of other banks and conversion into a limited company in 1896.

He twice married, his first wife being Mary Walker Leatham, of the well-known Yorkshire family, by whom he had two sons and one daughter, of whom only one, Robert Barclay, is now living. On his marriage, he took up his residence at the Limes, Walthamstow, coming into possession of Knott's Green on his father's death. His second wife, Margaret Exton, of Hitchin, survives him, together with her three sons and two daughters.

Mr. Barclay was a Quaker. He read a great deal of both scientific and ordinary books up to within a few years of his death, and never lost his power of taking interest in what was going on around him. He died April 25, 1898, at Exton House, Brighton, in his 82nd year.

He was elected a Fellow of this Society on March 19, 1862.

HAMAR ALFRED BASS, M.P., was the second son of the late Michael Thomas Bass, and a younger brother, therefore, of Lord Burton, to whose baronetcy he was heir-presumptive by a special remainder. He was born on June 30, 1842, and was educated at Harrow.

He entered Parliament in 1878 as one of the Members for Tamworth. In 1885, the separate representation of Tamworth having been abolished by the Redistribution Act, Mr. Bass stood for the Western Division of Staffordshire, and was elected by a majority of 714 over his Conservative opponent. In 1886 Mr. Bass, having, unlike his brother, allied himself with the Liberal Unionist party, was returned without opposition, and in 1892 he polled 5227 votes against 2879 given for a Gladstonian candidate. His return at the last general election (1895) was again unopposed. Mr. Bass seldom took part in the debates of the House of Commons, but was a staunch believer in, and upholder of, the Liberal Unionist policy.

He was a director of the well-known brewing firm of Bass and Company, and was well known in Burton-on-Trent, where he had two residences. Mr. Bass was a Magistrate and Deputy Lieutenant for Staffordshire, and Lieutenant-Colonel and Honorary Colonel of the 4th Battalion Prince of Wales's (North Staffordshire) Regiment.

He was elected a Fellow of this Society on December 19, 1894.

WILLIAM BELK, son of the late Mr. Thomas Belk, Recorder of Hartlepool, was born on February 6, 1849. After being educated at the Royal Grammar School, Lancaster, he served an apprenticeship of five years to Messrs. Thomas Richardson & Sons, mechanical engineers, of Hartlepool. He was subsequently employed by that firm in their marine engine department, and in erecting machinery abroad.

In October 1874, Mr. Belk was appointed assistant to Mr. John Howkins, then engineer to the Hartlepool Port and Harbour Commissioners, and on the resignation of that gentleman in July 1877 he succeeded to the post, which he held until his death. Among the works which Mr. Belk carried out as engineer to the Commissioners may be mentioned the construction of a breakwater at the Heugh, the deepening by means of dredging of the approach to the harbour and docks, the improvement of the lighthouse, and the erection of sea walls and groins.

Mr. Belk died on July 16, 1898, at the comparatively early age of 49.

He was elected a Fellow of this Society on March 19, 1890.

JOHN EDMUND CHANDLER, F.R.G.S., who died in December 1898, aged 38, was well known in the yachting world. For many years he was the owner of the steam yacht *Heather Bell*, which he sold to Lord Dunsandle about eighteen months ago. He invariably wintered abroad; indeed, the greater part of his life was spent in the Mediterranean. He was one of the founders and the Commodore of the Sussex Yacht Club at Southwick, and was also a member of the Royal Thames Yacht and St. Stephen Clubs. Mr. Chandler was until recently a partner in the firm of Messrs. Chandler & Co., brewers, London.

He was elected a Fellow of this Society on January 15, 1896.

JEREMIAH JAMES COLMAN was the only son of Mr. James Colman, of Stoke Holy Cross, Norwich, and was born in 1830.

He was the head of the firm of Messrs. J. and J. Colman, the celebrated mustard, starch, and blue manufacturers, of Carrow Works, Norwich. In 1862-63 he was Sheriff, and in 1867-68 Mayor, of Norwich. He entered Parliament in 1871 as Liberal Member for Norwich, and continued to represent the same constituency until 1895, when he retired.

Mr. Colman was a noted agriculturist and breeder of stock, and took many prizes at the Smithfield, Royal Agricultural, and other shows. He was also a generous supporter of philanthropic movements.

He died at his seaside residence, The Clyffe, Corton, near Lowestoft, on September 18, 1898, aged 68 years.

He was elected a Fellow of this Society on June 17, 1891.

HENRY GALE was born at Winchester in the year 1836. He was educated at Marlborough College, and on leaving became a pupil of Mr. Alfred Giles, M.Inst.C.E., and was with that gentleman in Canada on railway work. On his return to England he was employed by Sir James Brunlees on the works of the Ulverston and Lancaster Railway, now part of the Furness Railway system. In 1858 he joined the staff of the Madras Railway Company, and was engaged on the North-West line of that company for three years, when the construction was suspended by the Government and he returned to England. He was then again engaged by Sir James Brunlees, with whom he remained until about 1866, when he returned to India, and carried out extensive works there in connection with the North-West line.

Subsequently he was connected with various important enterprises both at home and abroad, and in 1876 went to Brazil to carry out the construction of the Donna Theresa Railway (a single line, 73 miles in length) for Messrs. Cutbill, Son, and De Lungo, and the late Mr. James Perry. A striking feature in this contract, and one which brought out prominently Mr. Gale's professional ability and independent judgment, was the unexpected necessity for protecting the line from the extraordinary sand-drifts which occasionally visited the locality. Although not contemplated in the contract price, Mr. Gale, on behalf of the firm, at once erected enormous sand-shields of corrugated iron at the more exposed points of the line, and thus avoided not only continuous labour in keeping the line clear, but, in times of exceptionally heavy storms, the absolute burying, if not the total destruction, of the line.

For some years Mr. Gale continued to represent Messrs. Perry, Cutbill, and Co. in South America, in connection with their extensive contracts there. He also, on behalf of the firm, sent in plans to the Government of Uruguay for the Montevideo Port Works, which were recognised as some of the best designs presented.

In 1888 Mr. Gale made his headquarters at the London office of Messrs. Cutbill and Co. as their Chief Engineer and adviser during the construction of the Midland of Uruguay Railway, the South Western of Venezuela Railway, the San Eugenio Railway, the Cordova and North Western Railway, and other works. In 1892 the business of Messrs. Perry, Cutbill, and Co. was converted into a limited company under the style of The Railway and Works Company, of which Mr. Gale acted as Engineer and one of the Managing Directors.

Mr. Gale died at Bournemouth on March 3, 1898. He was held in high esteem by his many professional friends, on account not only of his acknowledged ability as an engineer, but also of his many excellent and endearing personal qualities.

Mr. Gale was a Member of the Institution of Civil Engineers, and a Fellow of the Royal Geographical Society.

He was elected a Fellow of this Society on December 18, 1889.

JOHN HIPPISLEY, F.R.S., was the eldest son of the late Rev. Henry Hippisley, and was born at Lamborne Place, Berkshire, October 29, 180[illegible]. He was educated at Rugby under Dr. Wooll, and at Oriel College, Oxford. He graduated in 1825, taking a second class in both classics and mathematics. He twice married: first, in 1831, to Anne Elizabeth Clare, by

whom he had three sons and two daughters, of which family three survive; and secondly, in 1843, to Georgina Dolphin, by whom he had two sons and two daughters, of which family also three survive.

Mr. Hippisley possessed considerable mechanical ability, and was devoted to astronomy. He built an observatory at Ston Easton Park, near Bath, and constructed an excellent reflecting telescope there, casting and grinding its 9-inch speculum with his own hands, and making the body of the telescope, and also the driving clock, himself. He personally designed and constructed the machine by which he ground and figured his speculum, and made many other machines and models not so closely connected with astronomy. He was also an artist of much talent, and continued to paint in oils till quite recently.

He died on April 4, 1898, in his 95th year.

He was elected a Fellow of this Society on May 7, 1850.

FRANK MEAD, born at Peckham on October 28, 1852, was educated first at Dulwich College and subsequently at a private school at Reigate. He then entered the office of his father, Mr. C. R. Mead, who was at that time Engineer to the Sutton Gas Company. When the latter, in 1873, became Engineer to the Bournemouth Gas- and Water-works, Frank Mead was appointed his successor at Sutton, and held the post of Engineer to the Gas Company of that town for twenty-four years. During that period works were erected, from his designs and under his superintendence, for the maufacture, purification, and treatment of 500,000 cubic feet of gas per day.

Mr. Mead also acted as Engineer to the Gas Companies of Newhaven, Reigate, Leatherhead, and Oxted, for the last of which he designed and carried out entirely new works, and to the Leatherhead Water Company. He was professional adviser to the Colombo Gas Company, and he designed gasworks for Kow-Loon, near Hong-Kong, and subsequently had charge of the development and reconstruction of the Hong-Kong Gasworks.

Mr. Mead died on April 4, 1897, from peritonitis. In character he was painstaking and high principled, kind hearted and unostentatious, and his genial manner and sociability made him universally liked. He was ever ready to assist, quite in a simple way, which rendered his aid doubly welcome. He was a promoter and constant supporter of the Sutton Scientific Society, before which he read several papers, and he took great interest in the University Extension movement. He was also a skilled musician, and for some years gave his services as organist at Christ Church, Sutton.

Mr. Mead was an Associate Member of the Institution of Civil Engineers.

He was elected a Fellow of this Society on December 18, 1889.

HENRY PERIGAL was born April 1, 1801. He was the eldest of six children, the youngest of whom, Mr. Frederick Perigal, is now in his 87th year. He came of a long-lived family, his father, who reached the age of 99 years, being one of thirteen children, nine of whom attained a great age. He traced his ancestry back to Segui the Dane, who in 908

made a successful raid on Normandy, assumed the name of Perigal, and settled in France. The English branch of the family sprang from Gideon Perigal and his wife Madeline Duval of Dieppe, Huguenots who escaped to London. Henry Perigal belonged to the tenth generation of their descendants. He was remarkably vigorous until the last year or two, when his strength failed, and he died peacefully on June 6, 1898.

In early life he was a clerk in the Privy Council Office, but being pensioned somewhat early, joined Mr. H. Tudor, a family connection, in his stockbroking business. With the greatest regularity, he spent, for many years, his days in the office in Threadneedle Street, and his evenings at some scientific meeting, and his venerable figure was familiar at many scientific Societies.

Mr. Perigal joined this Society on June 4, 1850, and was elected on the Council on December 22, 1851. He was appointed Treasurer on May 24, 1853, and he held that office continuously until his death—a period of 45 years. The fortieth anniversary was celebrated by a Dinner given in his honour on April 15, 1893.

He was also a Fellow of the Royal Astronomical Society, Mathematical Society, Royal Microscopical Society, and the Royal Institution. Concerning this last, it is interesting to note that, though he attended the Friday evening lectures with great regularity, it was only as a visitor until 1895, when he celebrated his *ninety-fourth birthday* by becoming a Member of the Institution. One might search in vain the records of any other Society for mention of a candidate in his tenth decade.

Mr. Perigal's astronomical opinions were conspicuous for their heterodoxy, and it is a remarkable tribute to his personal character that, in spite of such opinions, he was the friend of men whose official positions led them to regard paradoxers generally with special disfavour. De Morgan has recorded in his *Budget of Paradoxes* what trouble these eccentric opinions have cost him; but he was indebted to Mr. Perigal for friendly help in making diagrams. In the records of the Royal Observatory there are bundles of letters from circle-squarers and others, which show how little reason the late Astronomer-Royal can have had to regard the writers with affection (though he always answered them courteously); yet he was no less glad to see Mr. Perigal at his ninetieth birthday celebration than was the latter to come, and it was always a pleasure to see Mr. Perigal at the dinners of the Royal Astronomical Society Club, of which he was elected a member on June 17, 1853, his proposer being De Morgan. Such facts as these are sufficient to show the remarkable way in which the charm of Mr. Perigal's personality won him a place which might have seemed impossible of attainment for a man of his views; for there is no masking the fact that he was a paradoxer pure and simple, his main conviction being that the moon did not rotate, and his main astronomical aim in life being to convince others —and especially young men not hardened in the opposite belief—of their grave error. To this end he made diagrams, constructed models, and wrote poems; bearing with heroic cheerfulness the continual disappointment of finding none of them of any avail. He has, however, done excellent work apart from this unfortunate misunderstanding. He was an excellent lathe-worker; he has written on the geometry of lathe-

work, on the laws of motion, on the methods by which the Pyramids were built, on harmonic motion, cycloidal curves, etc.

Mr. Perigal never married, but leaves a large number of nephews and nieces.

A portrait of Mr. Perigal is given as a Frontispiece to this volume. This has been reproduced from a photograph taken by Mr. A. Stroh, who has kindly placed the negative at the disposal of the Society.

Sir RICHARD QUAIN, Bart., M.D., LL.D., F.R.S., was born on October 31, 1816, at Mallow, Co. Cork, being the son of a clergyman. At an early age he trained for medicine, and became an early and very distinguished graduate of the London University. Subsequently he became a Fellow of the Royal College of Physicians (where he held in succession the highest offices), and Physician to the Hospital for Consumption and Diseases of the Chest, Brompton, and afterwards consulting Physician.

Later on he was appointed President of the General Medical Council, and Physician Extraordinary to the Queen.

Sir Richard Quain was the editor of the famous *Dictionary of Medicine* which bears his name, and of various original papers on diseases of the heart, and was one of the foremost physicians of the day, remaining in practice till within a few months of his death. He was universally respected, and enjoyed a great reputation.

He died on March 13, 1898, at the ripe age of 81.

He was elected a Fellow of this Society on March 16, 1892.

APPENDIX IV.

BOOKS, ETC., PURCHASED DURING THE YEAR 1898.

BOOKS AND PAMPHLETS.

DISTURNELL, J.—Influence of Climate in North and South America. 8° (1867).

EVANS, J.—A Revision and Explanation of the Geographical and Hydrographical Terms, and those of a Nautical Character relating thereto. 8° (1824).

GLAISHER, J.—On the Temperature of the Air at Jerusalem. 8° (1898).

HENNEN, J.—Sketches of the Medical Topography of the Mediterranean. 8° (1830).

HIGGINS, W. M.—The Earth: its Physical Condition, and most remarkable Phenomena. 8° (1836).

HUGHES, E.—Outlines of Physical Geography. 5th ed. 8° (1855).

HUTCHINSON, G.—Essays on Unexplained Phenomena. 8° (1838).

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LAW OF STORMS. 8°.

LONDON.—Observatories in London and its Vicinity. 8° (1852).

LOS ANGELES.—Eine Blume aus dem Goldenen Lande oder Los Angeles. 8° (1878).

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RADCLIFFE, C. B.—Behind the Tides. 8° (1888).

THURSTAN, E. P.—Southborough as a Health Resort. 8° (1885).

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WHITE, M.—Remarks on the Winds, Tides, and Currents of the Ocean. 8° (1846).

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LANTERN SLIDES.

CAMBERWELL TORNADO, October 29, 1898 (6 slides).
CLOUD EFFECTS (3 slides).
ESSEX TORNADO, June 24, 1897 (5 slides).
GREENWICH ANEMOGRAM, October 29, 1898.
KITE EXPERIMENTS at Blue Hill Observatory, Mass., U.S.A. (8 slides).
MAP of district round H.M.S. *Worcester* at Greenhithe.
WAVES (7 slides).
WEST INDIAN HURRICANE, September 1898 (3 slides).
WIND-FORCE COMMITTEE on board H.M.S. *Worcester*.

APPENDIX V.

DONATIONS RECEIVED DURING THE YEAR 1898.

BOOKS AND PAMPHLETS.

Presented by Societies, Institutions, etc.

ADELAIDE OBSERVATORY.—Rainfall in South Australia and the Northern Territory, 1895 and 1896.

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TEASDALE, W.—Portrait of Henry Perigal, F.R.A.S.

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PHOTOGRAPHS.

MAWLEY, E.—Bean in Flower at Exmouth, January 25, 1898.—Effect of Gale at Northlands, Salisbury, March 3, 1897.—Snow Scene at Keith, N.B., February 4, 1897.

ROTCH, A. L.—Kite Experiments at Blue Hill Observatory, Mass., U.S.A. (12 photos.).

APPENDIX VI.

REPORTS OF OBSERVATORIES, ETC.

THE METEOROLOGICAL OFFICE.—Lieut.-Gen. Sir R. Strachey, R.E., G.C.S.I., F.R.S., Chairman of Council; Robert H. Scott, D.Sc., F.R.S., Secretary.

MARINE METEOROLOGY.—*Meteorological Charts for the District between the Cape of Good Hope and New Zealand.*—These charts, which have been for several years in hand, are now passed for press and will shortly be issued. Among other interesting features presented by the discussion of the district, may be noted the preparation of wind-roses, showing the direction of wind areas bounded by 3° of latitude and 10° of longitude; these will probably be found of value to seamen when deciding on the relative advantages of a passage from Australia to England by the Cape of Good Hope or by Cape Horn.

South Atlantic Ocean.—The extraction of data from the logs of the Meteorological Office, and from those of the Royal Navy, has now been completed, and considerable progress has been made in the calculation of mean results for small areas.

Weather Telegraphy.—No material change has taken place in this department. The increase in quantity of reports of sunshine in the *Weekly Weather Report* is very marked and shows the popular interest in the subject. In the beginning of 1890 the number of stations furnishing weekly sunshine records was 34, in 1899 it is 60.

Land Meteorology of the British Isles.—The volume of *Results of Observations from Stations of the Second Order* for 1895 has been published.

The proposal for publishing the data from certain foreign stations, which exist in the office, and to which allusion was made last year, has been approved, and a good deal of progress has been made with the work. The volume of

Hourly Mean Readings for the Five Observatories for 1895 is now ready, and it contains, as an appendix, the mean values for the lustrum 1891-95 for the several observatories.

Atmospheric Electricity.—The Council have obtained from the Royal Society a grant for the prosecution of an investigation of this difficult subject. Mr. C. T. R. Wilson has been requested to undertake the inquiry.—*January* 30, 1899.

ROYAL OBSERVATORY, GREENWICH.—W. H. M. Christie, C.B., M.A., F.R.S., Astronomer-Royal.

The building of the east and west wings of the Physical Observatory, which was completed during the year, interfered seriously with the meteorological conditions and arrangements of the Observatory enclosure, and it became necessary, as a first step in the plan projected for the due maintenance of the meteorological work, to remove the radiation thermometers in November to the new Magnetic Pavilion ground, which had then become available for the purpose. (This ground is rather more than 300 yards east of the Observatory.) The revolving stand with standard thermometers was removed to the new site at the beginning of this year. In other respects the meteorological work has been carried out as in former years, the sunshine instrument being maintained in its new position on the roof of the Octagon Room, and the other self-recording instruments being kept in their usual state of efficiency.

The temperature during the year ranged between 92°·1 on September 8, and 26°·1 on February 21; and the yearly mean was 51°·3, being 1°·8 above the average. The recorded sunshine amounted to 1415 hours, being less than the amount recorded in 1897 by 128 hours. In September the sunshine amounted to 57 per cent of the possible duration.

The rainfall for the year, 18·85 ins., was exceptionally small, being 5·46 ins. below the average for the preceding 57 years, and was smaller than the rainfall in every year back to 1884, when the fall amounted to 18·05 ins. Rainfall was deficient in each month (with the exception of May, October, November, and December); and the fall in September, which amounted to 0·30 in., was the smallest September fall on record, excepting that for September 1865, when the amount was only 0·16 in. The rainfall in August was likewise exceptionally small.—*April* 17, 1899.

ROYAL OBSERVATORY, EDINBURGH.—Ralph Copeland, Ph.D., F.R.S.E., Astronomer-Royal for Scotland.

The daily meteorological register has been carried on without interruption throughout the year. Readings are made, at 9 a.m. and 9 p.m., of the standard barometer, and of the protected and exposed maximum and minimum thermometers, and dry and wet bulb thermometers. Copies of these readings, along with estimates of the direction and force of the wind, and of the amount and description of cloud, in monthly schedules, have, as in the preceding two years, been sent to the Scottish Meteorological Society, and abstracts of them have been printed in the Returns of the Registrar-General for Scotland.

The King's barograph and Robinson's anemometer have been kept in operation, and complete records by these instruments for the whole year have been secured. The tabulation and discussion of the hourly values of the anemometer curves is in Mr. Ramsay's hands.

Amongst occasional meteorological phenomena observed may be mentioned the following:—Lunar rainbows on three occasions—January 8, October 25, and December 27; auroræ of remarkable brightness on March 15 and April 12, on

the latter date the characteristic auroral lines in the spectrum being well seen; a solar halo on May 28; and a mock moon on the night of August 4.

The weekly readings of the rock thermometers at Calton Hill have been continued as in former years. These thermometers have now been read for a period of close on 20 years, having been bedded in the rock in June 1879, to replace the original set, which had been similarly observed from 1837 to 1876. In all, nearly 59 years of these observations are available.—*January* 31, 1899.

KEW OBSERVATORY, RICHMOND, SURREY.—Charles Chree, Sc.D., F.R.S., Superintendent.

The self-recording instruments for the continuous registration of atmospheric pressure, temperature of air and wet-bulb, wind (direction and velocity), bright sunshine, and rain have been maintained in regular operation throughout the year, and the standard eye observations for the control of the automatic records duly registered. The tabulations of the meteorological traces have been regularly made, and these, as well as copies of the eye observations, with notes of weather, cloud, and sunshine, have been transmitted, as usual, to the Meteorological Office.

With the sanction of the Meteorological Council, data have been supplied to the Council of the Royal Meteorological Society, the Institute of Mining Engineers, and the editor of *Symons's Monthly Meteorological Magazine.*

Electrograph.—This instrument worked in a satisfactory manner till May, when the action markedly deteriorated. Tests of the battery showed that its E.M.F. had fallen off considerably; this was so far remedied by cleaning and recharging the top row of cells. At the same time a new silk suspension was fitted to the needle of the electrometer, and the instrument generally overhauled, and a new scale determination was carried out. The records remained satisfactory until November, when the battery potential again began to fall off rapidly. Between November 24 and 27 the whole sixty cells were cleaned and recharged, with a satisfactory result; and on the latter date one-third of the cells were removed to contract the scale, in order to record high winter values, as explained in last year's Report.

In May another portable electrometer, No. 80, was purchased from White of Glasgow; it is furnished with some additions to the usual pattern, which experience at the Observatory suggested as likely to prove beneficial in reducing induction effects. This electrometer has been used since, with the older instrument, White, No. 53, in obtaining the scale value of the self-recording instruments, determinations being made on February 7, April 1, May 26, June 16, September 6, and November 28.

Atmospheric Electricity.—The comparisons of the potential, at the point where the jet from the water-dropper breaks up, and at a fixed station on the Observatory lawn, referred to in last year's Report, have been continued, and the observations have been taken twice every month.

During October some simultaneous observations were made with the two portable electrometers—the one situated on the pillar in the garden, the other at the same height on a tripod stand, at some distance in the park. It is hoped that time will be found to repeat the experiments on sufficiently numerous occasions to allow some conclusions to be drawn.

Fog and Mist.—The observations of a series of distant objects, referred to in previous Reports, have been continued. A note is taken of the most distant of the selected objects which is visible at each observation hour.

Aneroid Barometers.—The experiments referred to in the last three Reports were continued in the early part of the year. The results have been discussed

by the Superintendent in a paper recently published in the *Philosophical Transactions.*

Platinum Thermometry.—Experiments have been continued at the Observatory on the fixity of zero, and the general behaviour of platinum thermometers, which have shown, amongst other things, the expediency of carefully checking the behaviour of the "leads."

Experimental work on the comparison of platinum and mercury thermometers has also been continued, and it is hoped that it will shortly be possible, utilising the results of Dr. Harker's work at Sèvres, to issue certificates to high range mercury thermometers embodying the results of direct comparison.

Mercury Thermometry.—The experiments on thermometers of different kinds of glass made by Messrs. Powell and Sons have been continued. Further thermometers are being made by Messrs. Powell, of a pattern suggested by the Superintendent, with which it is hoped to experiment at higher temperatures.

During the year 1898 the air temperature ranged from 26°·0 on February 21 to 88°·3 on September 8. The mean was 51°·1. The maximum temperature in the sun's rays (black bulb *in vacuo*) was 144° on August 18 ; whilst the lowest temperature on the ground was 16° on February 21 (a temperature as low as 17° was recorded on the morning of April 5). 1452 hours of sunshine were registered, giving a mean percentage of 31, which is 2 per cent above the average for the last 20 years. The sunniest month by far was September, with 55 per cent, which is 20 per cent above the average for that month, and has only once been exceeded, viz. in 1895, when it was 56 per cent. September was also conspicuous for clear skies, only 2 days being wholly overcast, and the average cloudiness being only 4·1. The total rainfall was 18·220 ins., which is 5·815 ins. below the average for the last 35 years, and is, in fact, the lowest rainfall since 1870. The greatest and least monthly falls were respectively 3·345 ins. in October and 0·420 in. in September, the latter being the smallest September fall ever registered at Kew Observatory.—*March* 23, 1899.

RADCLIFFE OBSERVATORY, OXFORD.—A. A. Rambaut, M.A., D.Sc., Radcliffe Observer.

The meteorological observations and automatic registrations have been maintained as usual, and the results have been regularly sent, as heretofore, to the Meteorological Office (by telegram), the Registrar-General, the local newspapers, the *Windsor Chronicle* (rainfall only), and to sanitary and other public authorities on request, as well as to some private inquirers.

The underground platinum resistance thermometers continued, in the early part of the year, to give considerable trouble, serious discrepancies occurring in readings taken with them. After a long series of observations and experiments, these discrepancies were traced to uncertainties in the contacts at the switch-board, and to a want of thorough insulation in the leads. In October, new leads of an improved kind were attached to the thermometers, and means were taken to ensure more perfect contact at the switch-board. Since then the instruments seem to have been performing in a thoroughly satisfactory manner.

The following are the chief characteristics of the weather noted at Oxford in the year 1898 :—

The mean reading of the barometer was 29·760 ins., being 0·036 in. above the mean for the preceding 43 years. The highest reading, 30·439 ins., occurred on January 28, and the lowest, 28·521 ins., on November 25—a range of 1·918 in.

The mean temperature of the air was 50°·8, being 2°·0 above the mean for the preceding 70 years.

The following table exhibits the monthly differences from the mean of 70 years; the excess of warmth for the last 5 months is remarkable:—

January	+5°·8	May	−1°·5	September	+4°·8
February	+1·5	June	−1·2	October	+3·1
March	−2·0	July	−0·2	November	+2·8
April	+1·4	August	+3·0	December	+6·3

The maximum temperature in the air, 89°·9, occurred on September 8; the minimum, 22°·8, on February 21; the lowest on the grass, 10°·5, on February 21.

The amount of bright sunshine registered in 1898 by a Campbell-Stokes recorder was 1460 hours, or 28 hours in excess of the mean for the preceding 18 years. May was 57 hours below, and September was 75 hours above, the average.

The rainfall for the year amounted to 19·948 ins. on the ground, being 6·314 ins. below the mean for the preceding 83 years. The following table shows the monthly differences from the mean of 83 years:—

	Ins.		Ins.		Ins.
January	−1·448	May	+0·461	September	−2·311
February	−0·328	June	−0·914	October	+2·096
March	−0·886	July	−2·017	November	−0·391
April	−0·363	August	−0·765	December	+0·552

February 14, 1899.

SOIL TEMPERATURE.

By HENRY MELLISH, F.R.Met.Soc.

[Read April 19, 1899.]

Since the establishment by the Royal Meteorological Society of its climatological stations, the records of the temperature of the soil at various depths have been published regularly, for a number of stations, in the *Meteorological Record*. In 1886 Mr. W. Marriott read a paper before the Society [1] dealing with the records for the lustrum 1881-85; the present paper is an attempt to carry on the discussion down to the present time, especially in regard to the relation of the temperatures to the varying character of the soil.

In Mr. Marriott's paper is a table giving the temperature of the soil for each month on the average of the five years for all stations at which the observations were complete. For convenience of reference, this table is repeated here as Table II. (A); Table II. (B), giving the mean temperature of the air for the same period, is also taken from the same source. I have added to the latter the mean temperature of the air at 9 a.m. for the stations where the temperature of the soil is recorded at depths of 3 ins. and 6 ins., as it may well be that at these slight depths the soil temperature will bear a closer relation to that of the air at the time than to the mean of the day. Tables III. and IV. (A and B) give in precisely the same form the same information for the two following lustra, 1886-90 and 1891-95 respectively. During the period there have been, of course

[1] *Quarterly Journal*, vol. xii. p. 253.

a certain number of changes in the stations, and there are comparatively few for which the records are complete for the whole fifteen years.

In order to utilise to the most the observations of all the stations, I have added another table (Table V.), in which the means are given for the whole period for which the observations are complete at each station. As between one station and another, these values are, no doubt, not directly comparable; but at any one station the means for the different instruments all refer to precisely the same period and are therefore comparable with each other. Thus we cannot infer from the table that at a depth of 4 ft. the soil is 0°·1 warmer at Southampton than at Rousdon, as the observations do not refer to the same period; but we may infer that at Rousdon the temperature of the soil at a depth of 4 ft. is 3°·6 lower during the warmest month of the year than at a depth of 1 ft., and that at Regent's Park the corresponding difference is only 2°·4; and though the periods of observation at the two stations do not coincide, it seems reasonable to expect that, provided they represent the averages of a fair number of years, differences of this character are not likely to be substantially affected by this want of coincidence. In most cases, the observations have been incorporated up to the end of 1897, but in a few instances some of the early months of 1898 have been included, where required, to complete an even period of twelve months. At a few stations the period of observation was too short to furnish reliable averages, but they have been given because the temperatures were taken at a number of different depths; *e.g.* North Thoresby, where five soil thermometers were employed, but where the observations unfortunately only lasted for less than three years. Where the observations of some of the instruments at a station have been missing for any month, the value has usually been estimated from those that were complete; but where all the observations at the station have been wanting, the month has been altogether omitted. Means affected by interpolation are printed in italics: and on the whole, they are not numerous.

The last two columns in Table I. give the number of years and the period for which the means are given in Table V. In this table the stations are arranged by counties from north to south, and particulars are also given of the geological formation and nature of the soil. These particulars have been supplied in most cases by the observers, to whom I wish to express my best thanks. At stations where the observations have ceased, the information has been derived from the geological maps, and from the notes printed in Mr. Marriott's annual reports on the inspection of the stations.

At the bulk of the Society's stations the instruments used are of the pattern introduced by Mr. Symons, in which the thermometer is withdrawn from the tube for observation. One great advantage of this pattern is that it renders periodical re-verification of the thermometer possible; and such comparisons have been made at the regular visits of the Society's inspector. In a few cases, however, the older pattern of instrument is used, in which the thermometer is permanently attached to the tube and can only be re-verified by digging up the latter. This type has been used at Lowestoft and Regent's Park, and these thermometers have consequently remained unverified for a number of years. When visiting Lowestoft in September 1896, Mr. Marriott, however, succeeded in testing the instruments, and found that the 1 ft. thermometer had slipped down

TABLE I.—PARTICULARS OF ENGLISH STATIONS.

STATION.	County.	Height above Sea.	Geological Formation.	Nature of Soil.	State as to Moisture.	Period employed in Table V. No. of Years.	From	To
		ft.						
Alnwick . .	Northumberland	213	Carboniferous Limestone .	Sandy	...	3	1881	1883
Newton Reigny	Cumberland .	579	,, ,, .	...	...	8	1885	1892
Rounton . .	Yorks . .	242	Boulder Clay of great thickness resting on New Red Sandstone	9 to 12 ins. of alluvial soil over clay	Drained	15	1883	1897
Southport .	Lancaster . .	21	Pure blown sand, several feet, resting on marls and clays of New Red Sandstone	Sand	1 ft. dry; 4 ft. generally just under water line; 10 ft. water-logged	5	1893	1897
Bolton . .	,, . .	390	Middle Coal Measures .	18 ins. sandy loam, then fine gravel	Fairly dry . . .	12	1886	1898
North Thoresby	Lincoln . .	46	Hesle clay and purple boulder clay and gravels over chalk at about 90 feet	0 to 1 ft. heavy soil; 1 to 7½ ft. red clay, sometimes gravel	In summer, dry to about 6½ ft.; in winter, dry to about 2 ft.	3	1892	1895
Hodsock . .	Nottingham .	56	New Red Sandstone, "Bunter"	Sand, sand-rock within 2 ft.	Dry	16	1882	1897
Southwell .	,, .	97	Alluvial, overlying New Red Sandstone, near junction of Bunter and Keuper	Black peaty, mixed with sand	Dry usually, but water-logged after continuous rain	8	1887	1895
Strelley . .	,, .	396	Magnesian Limestone, Permian	Loam, bands of red clay, rock 20 ins. from surface, made ground	Dry	8 {	1882 1895	1886 1898
Somerleyton .	Suffolk . .	50	Alluvial	Clay loam, some gravel .	Dry generally, but somewhat water-logged after continuous rain	5	1891	1896
Lowestoft .	,, . .	85	Norwich Crag . . .	Sand and gravel . . .	Dry	17	1881	1897
Aspley Guise .	Bedford . .	410	Lower Greensand, 100 ft. thick	A few inches of vegetable mould, then sand	Dry	17	1881	1897
Bennington .	Hertford . .	407	Gravel, sand, and clay in patches over chalk at 80 ft.	Sandy loam . . .	Dry	7	1891	1897

				flints, then yellow clay and flints	S., and is drained by a railway cutting			
Camden Square	**London**	123	London Clay	Garden mould resting on clay	Moist	27	1871	1897
Regent's Park	,,	125	,, ,,	Garden mould resting on tenacious yellow clay	Wet	17	1881	1897
Greenwich	,,	159	Lower London Tertiaries	Beds of sand and of flint gravel more or less cemented	Dry	15	1881	1895
Norwood	Surrey	220	London Clay	Clay	Moderately dry	17	1881	1897
Isleworth	Middlesex	68	,, ,,	Loam or clay loam	Neither dry nor wet	5	1881	1885
Croydon	Surrey	201	Lower London Tertiaries	Light and rather gravelly loam on deep sand	Dry and porous; slope to N.	4	1881	1884
Cardiff	Glamorgan	43	Alluvial	Gravel on clay	...	5	1881	1886
Marlborough	Wilts	424	Upper Chalk	Alluvial loam	Practically dry, water level about 3 ft.	17	1881	1898
Margate	Kent	83	,, ,,	A few inches of light loam over the chalk	Dry	11	1887	1898
Tunbridge Wells	,,	425	Hastings Beds	Loam on sand-rock	Dry	8	1890	1898
Harestock	Hants	300	Chalk (somewhat cracked)	Slight streaks of clay near surface	Quite dry	15	1883	1897
Southampton	,,	136	Bagshot, etc., Beds	Light soil, 0 to 2 ft.; sand, 2 to 25 ft.	Dry to about 9 ft.	5	1887	1891
Brighton	Sussex	31	Chalk	Chalk	Very dry	5	1893	1897
Worthing	,,	33	,,	Loam and brick earth for 15 ft. over chalk	Fairly dry, water level about 24 ft.	15	1882	1897
Stowell	Somerset	376	Great Oolite	...	...	12	1884	1896
Cullompton	Devon	202	Permian	Deep, light garden soil over gravel and clay	Dry	8	1881	1888
Rousdon	,,	514	Upper Cretaceous based on Lias and Rhætic Beds	Red Script, very tough, half clay half gravel for 15 ft., over 75 ft. of chalk	Dry	12	1886	1897
Tavistock	,,	391	Devonian (limestone or bastard freestone)	6 ins. garden soil, then 2 ft. loam resting on limestone	Fairly dry, sometimes water-logged at 2 ft.	3	1895	1897
Babbacombe	,,	293	Devonian (limestone)	6 ins. garden soil, then clay and shale	Fairly dry, sometimes water-logged at 2 ft.	11	1881	1893

its case about 3°, and was consequently reading much too low. The 2 ft. thermometer was fully 1° too high. No correction has been applied for these errors, as it is uncertain when they may have begun to take effect. The Regent's Park instruments were got up in 1897, when it was found

TABLE II. (A).—MEAN SOIL TEMPERATURES, 1881-85.

STATION.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
3 Inches.													
Aspley Guise	36·9°	38·8°	40·1°	46·3°	54·9°	61·8°	65·1°	62·2°	56·8°	48·0°	41·9°	37·6°	49·2°
6 Inches.													
Aspley Guise	37·2	39·2	40·5	46·1	53·8	60·5	64·2	61·9	57·0	48·5	42·5	38·1	49·1
Marlborough	...	...	...	...	...	60·1	63·4	61·5	56·5	47·8	42·4	38·2	...
Babbacombe	...	...	...	...	...	...	...	...	59·0	51·9	47·2	42·2	...
1 Foot.													
Lowestoft	38·8	40·1	41·4	46·5	52·6	58·3	62·5	61·3	57·3	50·2	44·7	40·2	49·5
Aspley Guise	37·6	39·4	41·1	46·3	53·5	60·2	64·1	62·1	57·2	49·0	43·0	38·5	49·3
Regent's Park	38·7	40·0	40·7	45·4	52·9	59·2	63·1	61·9	57·0	49·5	43·9	39·9	49·4
Norwood	38·7	40·1	41·3	46·0	52·7	58·7	62·7	61·4	57·1	49·7	43·9	39·7	49·3
Isleworth	38·5	40·2	41·7	46·6	53·7	59·6	63·2	62·0	57·7	50·1	44·0	39·7	49·7
Cardiff	*41·2*	*42·6*	*42·9*	*47·1*	*52·8*	*58·4*	*61·8*	61·1	57·3	50·9	46·4	42·3	*50·4*
Marlborough	*38·7*	*40·4*	*41·9*	*46·9*	*54·2*	60·5	63·7	62·3	57·8	49·6	43·9	39·4	*49·9*
Southampton	40·8	42·2	43·7	48·5	54·5	60·0	63·3	62·2	58·5	51·2	46·3	42·0	51·1
Cullompton	40·7	42·4	43·6	47·3	53·5	59·1	62·2	61·8	57·7	50·7	46·1	41·3	50·5
Babbacombe	42·4	44·0	45·3	49·6	55·1	60·8	63·8	63·6	60·1	53·4	48·4	43·5	52·5
1½ Feet.													
Marlborough	...	...	...	...	...	59·7	62·9	62·4	58·5	51·1	45·2	40·7	...
2 Feet.													
Lowestoft	39·2	40·2	41·5	46·4	52·4	58·3	62·5	61·9	58·2	51·5	45·7	40·9	49·[illegible]
Aspley Guise	39·5	40·7	42·5	46·8	53·2	59·5	63·5	62·6	58·4	51·4	45·3	40·8	50·[illegible]
Isleworth	40·7	41·3	42·8	46·7	52·8	58·5	62·3	62·2	58·8	52·4	46·8	42·3	50·[illegible]
3·2 Feet.													
Greenwich	42·7	42·7	43·7	46·8	51·8	57·8	62·1	62·6	59·7	54·3	49·0	44·6	51·[illegible]
4 Feet.													
Lowestoft	42·2	42·0	42·8	45·7	49·8	54·7	58·7	59·1	57·1	52·7	47·9	43·8	49·[illegible]
Aspley Guise	41·9	41·8	43·0	45·7	50·3	55·8	59·7	60·4	58·0	53·3	48·1	43·7	50·[illegible]
Regent's Park	42·0	41·2	41·9	44·0	48·7	54·9	59·1	60·3	58·2	53·2	48·0	43·9	49·[illegible]
Cardiff	...	...	...	...	...	...	...	57·7	56·8	54·1	50·8	47·6	...

TABLE II. (B).—MEAN TEMPERATURE OF AIR, 1881-85.

STATION.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Ye[illegible]
Maximum and Minimum.													
Lowestoft	38·3°	40·9°	41·2°	45·1°	50·6°	55·8°	60·6°	59·7°	56·7°	49·3°	44·2°	39·6°	48·5
Aspley Guise	37·3	40·6	41·0	45·6	51·6	57·1	61·2	59·7	55·6	47·2	42·6	38·0	48·[illegible]
Regent's Park	38·8	42·0	42·6	47·5	53·5	58·9	63·0	61·6	57·3	48·7	44·5	40·0	49·9
Greenwich	38·4	41·9	42·4	47·4	53·8	59·3	63·7	62·2	57·2	48·6	44·2	39·7	49·9
Norwood	38·7	42·1	42·4	47·0	53·1	58·6	62·6	61·3	56·8	48·6	44·2	40·0	49·6
Isleworth	38·2	42·0	42·4	47·4	53·1	58·8	62·4	61·1	57·0	48·6	44·0	39·5	49·5
Cardiff	39·0	42·7	42·0	47·4	52·9	58·0	61·2	60·2	56·4	48·8	45·0	40·6	49·7
Marlborough	37·8	41·0	41·0	45·4	51·3	56·7	60·5	59·1	55·3	47·1	42·7	38·6	48·0
Southampton	38·7	42·2	42·3	46·9	52·1	57·6	60·8	60·2	56·4	48·6	44·3	40·0	49·2
Cullompton	39·0	42·0	42·4	46·3	51·7	56·8	60·1	59·1	55·7	48·6	45·0	40·6	49·[illegible]
Babbacombe	41·0	43·8	43·0	46·0	51·9	57·0	60·3	60·2	56·6	50·2	46·8	42·6	50·[illegible]
9 a.m.													
Aspley Guise	38·8	40·1	41·2	47·1	54·4	59·2	63·1	61·3	56·3	48·2	42·8	37·7	49·0
Marlborough	38·5	38·8	40·3	45·8	53·2	58·0	62·4	61·1	56·0	47·1	41·9	37·7	48·4

4 ft. thermometer was reading about 0°·4 too low. These facts point very strongly to the necessity of employing a pattern of ent which admits of being verified from time to time, and of the neter being graduated on the glass tube so that any displacement cale may be impossible.

TABLE III. (A).—MEAN SOIL TEMPERATURES, 1886-90.

ATION.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
nches.													
Reigny .	35·8°	34·8°	36·9°	41·6°	48·7°	55·2°	57·2°	55·9°	52·6°	46·3°	41·4°	35·9°	45·2°
Guise .	35·1	35·3	38·5	45·4	54·7	61·7	64·7	62·5	57·6	48·0	42·7	35·4	48·5
nches.													
Guise .	35·4	35·7	38·6	45·3	54·2	61·2	64·4	62·4	57·7	48·4	43·2	35·8	48·5
ough .	...	...	...	...	...	...	62·4	60·9	56·5	49·1	44·8	38·6	...
ck . .	36·9	36·1	37·7	42·8	50·7	56·9	59·5	58·5	55·0	47·6	43·8	37·4	46·9
npton .	37·8	37·2	39·8	46·4	54·9	61·0	63·3	61·8	57·3	49·1	44·9	38·4	49·3
ombe .	40·3	39·6	41·4	47·6	55·7	61·7	63·4	62·7	59·1	51·8	47·1	41·1	51·0
Foot.													
Reigny .	36·7	36·3	37·6	42·2	48·5	54·2	56·8	56·3	53·8	48·2	43·7	38·1	46·0
n . .	36·6	36·7	38·4	43·1	50·1	56·0	58·7	58·1	55·4	48·9	43·6	37·8	47·0
. .	...	...	...	...	...	...	59·2	58·2	55·3	58·4	44·0	38·4	...
k . .	36·6	37·0	39·0	44·3	51·5	57·3	59·8	59·4	56·3	49·2	44·2	38·0	47·7
oft . .	37·8	37·2	38·9	44·2	52·0	58·5	61·0	60·3	57·6	50·0	45·0	38·7	48·4
Guise .	35·6	35·9	38·6	45·0	53·5	60·6	63·9	62·2	57·9	48·7	43·6	36·6	48·5
nsted .	36·3	36·4	38·7	45·3	53·8	59·8	62·6	61·8	58·3	49·8	44·6	37·6	48·7
s Park .	36·4	35·8	37·5	43·7	51·9	59·1	62·2	61·2	57·4	48·7	43·9	37·4	47·9
d . .	36·6	36·3	38·3	44·6	52·4	58·9	61·9	61·2	57·9	49·5	44·8	38·1	48·4
rough .	...	...	...	...	...	...	62·6	61·3	57·1	49·9	45·5	39·5	...
e . .	39·2	38·1	39·7	45·7	53·2	59·6	62·2	62·0	59·1	50·9	46·4	40·0	49·7
ck . .	38·0	37·5	38·5	43·9	51·2	57·1	60·2	59·7	56·8	50·0	45·5	39·2	48·1
npton .	39·3	39·1	41·0	47·2	54·6	60·2	62·4	61·6	58·1	51·2	46·9	41.1	50·2
ng . .	39·1	38·4	40·3	46·4	54·1	59·8	62·3	62·0	59·2	51·5	46·9	40·0	50·0
. .	38·8	38·4	39·9	45·6	54·3	60·9	63·1	62·4	59·0	51·5	46·5	40·0	50·0
n . .	39·8	38·8	39·9	45·3	52·6	59·0	61·0	60·0	57·2	50·9	46·5	40·9	49·3
ombe .	41·1	40·7	42·2	48·4	56·0	61·9	64·0	63·4	60·2	53·2	48·4	42·5	51·8
Feet.													
Reigny .	37·9	37·5	38·1	42·1	47·3	52·5	55·6	55·8	54·1	49·5	45·1	40·1	46·3
. .	...	...	...	...	...	...	57·7	57·4	55·3	49·4	45·2	40·0	...
oft . .	38·3	37·6	38·8	44·1	51·6	58·0	61·1	60·9	58·8	51·5	46·3	39·9	48·9
Guise .	37·4	37·6	39·5	45·6	53·2	59·7	63·4	62·6	59·0	50·9	45·6	39·1	49·5
msted .	38·0	38·0	39·3	45·2	52·2	58·1	61·6	61·6	59·1	52·1	46·8	40·2	49·4
e . .	41·3	40·3	40·7	45·8	51·9	57·6	60·7	61·0	59·3	53·4	48·9	43·4	50·4
ck . .	39·6	39·1	39·3	43·6	49·7	55·2	58·7	58·9	57·0	51·3	47·3	41·8	48·5
n . .	41·2	40·6	40·8	45·3	51·3	56·9	59·7	59·4	57·6	52·6	48·5	43·4	49·8
Feet.													
Reigny .	38·5	37·9	38·1	41·3	46·0	50·7	54·2	54·8	53·7	50·1	46·0	41·4	46·1
2 Feet.													
ich . .	41·2	40·4	40·6	45·0	51·5	57·8	61·6	62·2	60·3	54·3	49·4	43·8	50·7
Feet.													
Reigny .	39·5	38·7	38·5	40·9	44·8	49·0	52·5	53·5	53·0	50·0	46·4	42·3	45·8
oft . .	41·0	40·2	40·4	43·9	49·0	54·2	57·2	57·9	57·0	52·5	48·2	43·4	48·7
Guise .	40·0	39·5	39·9	44·2	49·9	55·5	59·5	60·1	58·2	52·9	48·1	42·7	49·2
's Park .	39·7	38·8	38·3	42·2	47·7	53·9	58·6	59·5	58·1	52·8	47·6	42·6	48·3
ck . .	42·7	41·6	40·8	43·1	47·0	51·5	55·1	56·6	56·1	53·0	49·5	45·6	48·6
n . .	43·3	42·4	41·7	44·6	48·9	53·6	56·9	57·4	56·8	53·6	50·1	46·0	49·6

addition to the English observations, those at a number of Scotch s have been published for many years by the Scottish Meteorological

Society; in fact, they have a long start of us, some of their records back to 1857. I have accordingly extracted from the *Journal* o Society all observations of underground temperature for the perioc July 1863 to the end of 1892, with the exception of the two and hal from July 1880 to December 1882, the results of which have no printed. I have not been able to find much information in the So *Journal* as to the pattern of instrument used, or the practice as verification; but it seems likely that in most cases fixed thermo

TABLE III. (B).—MEAN TEMPERATURE OF AIR, 1886-90.

STATION.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec
Maximum and Minimum.	°	°	°	°	°	°	°	°	°	°	°	°
Newton Reigny	36·8	35·3	38·0	42·4	49·4	55·0	56·4	55·6	52·2	46·3	41·0	35·
Rounton	37·2	36·2	38·7	42·4	49·2	54·7	57·2	56·8	53·5	46·9	41·7	35·
Bolton	...	...	...	...	...	...	57·5	57·0	54·3	47·2	42·7	36·
Hodsock	36·9	36·7	39·6	44·0	51·4	57·2	59·7	58·6	54·9	47·6	42·5	35·
Lowestoft	38·1	36·7	39·3	43·4	50·3	56·4	59·3	59·4	57·3	49·6	44·2	37·
Aspley Guise	36·1	35·0	38·9	44·0	51·3	57·4	60·1	59·4	55·8	47·7	42·3	34·
Berkhamsted	36·3	35·4	39·2	44·2	51·5	57·7	59·9	59·4	55·9	47·8	42·8	35·
Regent's Park	38·0	36·6	40·3	45·7	53·4	59·7	61·9	61·2	57·3	48·7	45·0	36·
Greenwich	37·8	36·6	40·4	46·0	54·2	60·3	62·8	62·0	57·8	48·9	43·8	36·
Norwood	38·1	36·9	40·4	45·8	53·6	59·6	61·8	61·1	57·6	49·1	44·0	36·
Marlborough	...	...	...	...	...	...	58·4	58·0	54·1	46·5	42·2	35·1
Margate	38·6	37·1	39·9	45·7	52·0	57·6	60·7	60·8	58·2	50·0	45·0	37·
Harestock	37·3	36·3	39·4	44·5	51·8	57·6	59·8	59·2	56·0	48·1	43·3	36·
Southampton	37·9	37·1	40·2	45·6	53·1	58·8	60·7	60·0	56·8	48·7	43·9	36·
Worthing	38·5	37·3	39·7	45·2	52·7	57·8	59·9	59·9	57·7	50·0	45·2	37·
Stowell	38·1	36·3	39·5	44·5	51·9	57·2	59·3	58·6	55·5	48·1	43·7	36·7
Rousdon	39·1	36·7	39·3	44·3	50·7	56·7	58·1	58·0	55·7	49·1	44·6	38·4
Babbacombe	41·5	39·4	41·4	46·0	52·3	58·5	60·5	60·0	57·1	50·7	46·5	41·
9 a.m.												
Newton Reigny	36·4	34·3	38·0	43·1	50·3	56·2	57·5	56·8	53·4	46·2	40·7	34·8
Aspley Guise	35·9	34·6	39·3	44·4	53·1	58·8	62·2	61·4	56·6	48·5	42·8	34·8
Marlborough	...	...	...	...	...	...	60·7	59·9	55·5	46·4	41·9	34·7
Harestock	36·7	35·1	39·4	45·0	53·4	58·9	61·3	60·6	56·7	48·3	43·2	35·5
Southampton	37·4	36·3	40·3	46·4	54·8	60·5	62·6	61·7	57·7	49·5	44·3	36·6
Babbacombe	41·1	38·8	42·1	46·8	53·5	59·9	62·3	62·0	57·9	51·6	46·5	40·6

have been used which have not permitted of re-verification, in whicl some doubt must attach to their absolute values. In a paper b Buchan, published in 1863,[1] it is stated that the temperatures at Art and Barry were "taken by means of vessels of water sunk in holes t specified depth; the holes were made of drain-pipes, and were car closed at the top so as to cut off communication with the external the same thermometer was employed for the different depths. Sandwick the holes were lined with wood," and the same thermo was used for the 12-in. and 22-in. holes. At the other stations established "the thermometers were permanently sunk in the grou the required depths, with their scales projecting above the surface." Sandwick the observations were made weekly, at Arbroath and Ba longer intervals, and at other stations daily. The hour of observatio 9 a.m., except at Sandwick, when it was any convenient time, gen about the middle of the day. Interpolations have been more frequent

[1] *Quarterly Report of the Meteorological Society of Scotland*, December 31, 186

in the case of the English stations, and there are a good many months at different stations for which the observations are wanting. Particulars of the different stations are given in Table VI.; and the means for the whole period for which the observations are complete at each station are given in Table VII., which is prepared in the same way as Table V., except that no distinction is made in the case of months in which interpolated values are included in the averages.

TABLE IV. (A).—MEAN SOIL TEMPERATURES, 1891-95.

STATION.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
3 Inches.													
Aspley Guise .	33·8°	36·4°	39·9°	47·8°	55·5°	62·5°	63·8°	62·8°	57·5°	48·6°	42·8°	37·8°	49·1°
6 Inches.													
Aspley Guise .	34·0	36·8	40·0	47·5	54·8	62·0	63·5	62·5	57·6	49·0	43·2	38·3	49·1
Marlborough .	35·5	38·0	40·1	46·5	52·8	59·4	61·3	60·4	56·4	49·2	44·7	40·2	48·7
1 Foot.													
Rounton . .	35·3	37·0	39·0	44·4	50·3	56·4	59·2	58·8	55·5	48·6	43·5	39·1	47·3
Bolton . . .	35·2	37·1	38·4	43·8	50·4	56·8	59·3	58·8	55·3	48·4	43·2	39·1	47·2
Hodsock . .	35·3	37·3	40·0	45·9	51·9	57·4	60·1	59·7	56·4	49·6	44·1	39·5	48·1
Lowestoft . .	34·5	35·6	38·4	44·1	50·0	56·1	59·5	59·2	56·8	48·6	43·4	38·3	47·0
Aspley Guise .	34·2	36·9	40·0	47·1	53·8	60·9	62·6	61·6	57·3	49·0	43·2	38·5	48·8
Bennington . .	35·3	37·5	40·1	46·4	52·4	59·1	61·4	60·8	57·5	49·9	44·4	39·8	48·7
Berkhamsted .	34·6	37·5	40·7	48·3	54·6	61·0	63·1	62·4	58·5	50·5	44·5	39·4	49·6
Regent's Park .	34·5	36·7	38·7	45·5	52·4	59·3	62·1	61·5	57·4	49·8	44·1	39·4	48·4
Norwood . .	35·9	38·2	40·4	46·6	52·8	58·8	61·6	61·9	58·4	51·1	45·5	40·8	49·3
Marlborough .	36·6	38·8	40·7	47·5	53·8	60·0	62·0	*61·2*	*57·1*	50·2	45·5	41·1	*49·5*
Margate . .	37·4	38·8	41·0	47·4	53·3	59·7	62·9	62·6	59·5	52·4	47·3	42·6	50·4
Tunbridge Wells .	35·7	37·9	40·6	47·2	53·8	60·1	62·7	62·1	58·3	50·7	45·1	40·5	49·6
Harestock . .	35·4	*37·9*	*39·7*	46·4	52·3	58·4	61·0	60·7	57·5	50·6	45·3	40·8	*48·8*
Worthing . .	36·8	39·4	41·9	48·9	54·9	60·7	62·8	...	...	...	...	...	...
Stowell . .	36·3	38·9	41·0	48·0	54·2	61·0	62·9	62·5	58·8	51·2	45·9	41·6	50·2
Rousdon . .	36·9	39·1	40·8	47·5	53·1	59·4	61·2	60·9	58·0	51·4	46·2	42·2	49·7
2 Feet.													
olton . . .	36·6	38·0	38·9	43·5	49·3	55·0	58·1	58·1	55·6	49·7	44·5	40·8	47·3
owestoft . .	36·1	37·5	40·2	45·9	52·0	57·7	61·4	61·3	59·0	51·8	46·2	40·8	49·2
spley Guise .	36·0	38·3	41·0	47·5	53·9	60·4	62·7	62·2	58·7	51·4	45·2	40·7	49·8
rkhamsted .	36·5	38·5	40·9	47·6	53·5	59·4	62·2	62·0	59·3	52·6	46·5	41·6	50·1
argate . .	40·0	40·5	41·7	46·7	51·8	57·2	60·9	61·2	59·5	54·2	49·2	45·0	50·7
restock . .	37·2	38·9	40·0	45·4	50·8	56·2	59·5	59·8	57·6	52·1	46·8	42·6	48·9
usdon . .	39·5	40·9	41·7	47·0	52·0	57·1	59·6	59·7	58·2	53·4	48·3	44·5	50·2
3·2 Feet.													
enwich . .	40·1	*40·7*	*41·8*	46·7	52·0	58·0	61·7	62·0	60·3	55·1	49·6	45·1	*51·1*
4 Feet.													
erleyton . .	...	...	...	...	...	53·8	57·4	58·1	57·0	53·7	49·2	44·9	...
estoft . .	40·1	40·3	41·3	45·1	49·5	53·9	57·3	58·0	57·1	53·0	48·4	44·4	49·0
ey Guise .	39·2	39·9	41·2	45·6	50·7	55·7	58·8	59·4	57·9	53·2	47·9	43·8	49·4
nt's Park .	38·8	38·9	39·2	43·1	48·7	54·7	59·1	59·9	58·5	53·6	48·2	43·9	48·9
ate . .	43·7	42·9	43·0	46·0	49·9	54·0	57·1	58·9	58·5	55·6	51·6	48·0	50·8
tock . .	41·4	41·0	41·2	43·9	47·9	52·0	55·7	56·9	56·6	53·8	49·7	45·8	48·8
on . .	41·9	42·0	42·2	45·7	50·0	54·2	57·1	57·9	57·4	54·2	49·8	46·4	49·9
6 Feet.													
ock . .	44·5	43·1	42·7	43·8	46·4	49·5	52·7	54·5	55·1	54·0	51·3	47·9	48·8

ould certainly appear that the same confidence cannot be felt in acy of these observations as in those at the English stations; but

they have this advantage, that they are all taken at uniform depths— ins., 12 ins., and 22 ins.—at each station, and in several cases the per observation is a long one. At Barry, in addition to the depths menti observations have been made at 18 ins., 36 ins., and 48 ins.

TABLE IV. (B).—Mean Temperature of Air, 1891-95.

Station.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Maximum and Minimum.	°	°	°	°	°	°	°	°	°	°	°	°
Rounton	33·6	36·2	39·9	44·0	48·9	55·0	57·3	57·6	53·7	45·3	42·4	37·2
Bolton	35·2	37·7	40·9	46·3	51·0	56·6	58·2	58·1	55·1	46·7	43·2	38·5
Hodsock	34·5	37·0	41·6	46·1	51·4	56·9	59·4	59·8	55·7	47·3	43·2	37·9
Somerleyton	...	...	...	...	...	56·6	59·9	60·7	57·2	49·5	44·6	38·9
Lowestoft	35·1	37·4	40·8	44·8	50·0	55·7	59·6	60·4	57·4	49·5	45·3	39·6
Aspley Guise	33·7	36·7	41·3	47·1	51·9	57·8	59·8	60·0	56·2	47·4	42·9	37·9
Bennington	34·0	36·9	41·6	47·5	52·1	58·2	60·2	60·4	56·7	47·9	43·0	38·5
Berkhamsted	34·2	37·1	41·5	47·2	52·3	58·1	60·2	60·3	56·5	47·8	43·3	38·6
Regent's Park	35·5	37·9	42·3	48·7	54·1	60·1	62·0	62·1	58·0	49·1	44·8	39·7
Greenwich	35·4	37·8	42·8	49·0	54·6	61·0	62·8	62·9	58·7	49·4	44·7	39·9
Norwood	35·4	37·9	42·4	48·2	53·5	59·3	61·3	61·5	57·7	49·0	44·6	39·6
Marlborough	34·1	37·0	40·4	46·6	51·1	56·7	58·9	58·8	54·7	46·5	43·0	38·4
Margate	36·0	38·2	42·0	46·8	52·2	57·7	61·0	62·0	58·7	50·7	45·9	40·7
Tunbridge Wells	34·3	37·4	41·6	47·6	52·7	58·2	60·2	60·4	57·1	48·5	44·2	39·2
Harestock	35·0	37·8	41·8	48·0	52·4	58·3	60·0	60·3	56·9	48·1	44·0	39·4
Worthing	36·1	38·6	41·8	48·2	52·9	58·2	60·3	...	...	50·5	46·1	41·0
Stowell	35·3	37·9	41·4	47·7	51·9	57·8	59·3	59·4	56·2	47·8	44·3	39·9
Rousdon	36·5	38·6	41·5	47·0	50·8	56·4	57·9	58·4	56·2	48·8	45·1	41·6
9 a.m.												
Aspley Guise	33·5	36·0	41·5	48·1	54·0	59·8	61·3	61·7	57·5	48·2	42·9	37·7
Marlborough	33·6	35·6	40·3	48·2	54·0	59·3	60·9	60·9	56·6	47·1	42·7	37·8

In comparing observations made at different depths at only one of the day, it seems desirable to inquire what relation the value foı hour bears to the mean for the day, and whether this relation much with the different depths, as the time of occurrence of the max and minimum temperature will undoubtedly vary with the depth the surface. The observations published by our own Society d throw any light on this subject, but some information may be obt from a paper published by Dr. Buchan in 1869.[1] In this pap discussed a series of observations made at six stations during July] the observations were made at the three usual depths,—3 ins., 12 ins 22 ins.,—and were taken twelve times a day, between 6 a.m. and 1(The figures in Table VIII. are taken from this paper, in which the a\ of the twelve observations is taken as the mean for the day. W from this that at a depth of 3 ins. the temperature at 9 a.m. iı month is on the average of the six stations 1°·7 below the daily ranging from 1°·2 below at Feddinch to 2°·6 below at Thirlestan depths of 12 ins. and 22 ins. the differences between the 9 a.m. and the mean for the day are small and of no consequence. W‹ see that the range of temperature between 6 a.m. and 10 p.m., *i.* difference between the mean for the warmest and the coldest hour, at a depth of 3 ins. from 3°·5 at Dunrobin to 8°·5 at Thirlestane,

[1] *Journal of the Scottish Meteorological Society*, vol. ii. p. 273.

E V.—MEAN TEMPERATURE OF THE AIR AND SOIL FOR THE PERIOD STATED IN TABLE I.

TIONS.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.	Range.
WICK.														
n . .	36·7°	39·6°	39·5°	43·5°	49·5°	54·1°	58·2°	57·7°	53·7°	47·3°	42·3°	37·8°	46·7°	21·5°
. . .	38·8	39·2	41·0	46·0	53·4	58·8	61·4	60·8	56·5	49·8	42·8	38·7	48·9	22·7
. . .	42·6	42·4	43·8	47·4	53·3	59·0	61·6	61·5	58·4	53·5	47·6	43·6	51·2	19·2
REIGNY.														
n . .	36·0	36·6	37·3	42·4	48·6	54·6	56·4	55·3	52·2	45·3	40·6	35·3	45·1	21·1
M. . .	35·7	35·0	37·1	43·0	49·4	56·0	57·3	56·3	53·0	45·1	40·3	34·8	45·3	22·5
IS. . .	35·1	35·6	36·5	41·2	47·8	54·8	57·1	55·7	52·2	45·4	40·8	35·8	44·8	22·0
. . .	36·2	37·0	37·6	41·9	47·8	53·8	56·7	56·2	53·5	47·5	43·0	37·8	45·7	20·5
. . .	37·5	38·0	38·2	42·2	46·7	52·2	55·5	55·7	53·8	48·9	44·3	39·8	46·1	18·2
. . .	38·4	38·4	38·5	41·4	45·7	50·6	54·2	54·9	53·7	49·7	45·4	41·1	46·0	16·5
. . .	39·3	38·9	38·7	40·8	44·4	48·7	52·2	53·4	52·8	49·6	45·8	41·9	45·5	14·7
NTON.														
n . .	36·2	37·6	39·3	43·5	48·7	55·0	57·5	57·2	53·5	46·0	41·9	37·0	46·1	21·3
. . .	36·7	37·6	39·1	44·0	50·0	56·3	59·1	58·5	55·3	48·6	43·5	38·7	47·3	22·4
IPORT.														
n . .	36·7	38·8	43·3	47·3	51·5	58·0	60·0	59·8	55·4	47·6	44·0	40·5	48·6	23·3
. . .	37·3	38·6	41·7	47·0	53·2	59·5	62·1	61·3	56·9	49·7	44·6	40·8	49·4	24·8
. . .	41·5	41·0	42·3	45·6	50·3	55·1	58·6	59·5	57·7	53·5	48·6	45·2	49·9	18·5
TON.														
n . .	37·2	38·0	40·4	45·1	51·1	57·0	58·2	57·6	54·5	47·0	43·0	37·7	47·2	21·0
. . .	36·9	37·6	38·8	43·6	50·6	57·2	59·5	58·7	55·2	48·2	43·4	38·8	47·4	22·6
. . .	38·1	38·6	39·3	43·3	49·3	55·3	58·2	58·0	55·3	49·5	44·7	40·4	47·5	20·1
HORESBY.														
n . .	34·6	36·6	43·4	46·7	50·5	56·5	59·0	60·6	54·7	48·5	43·7	38·5	47·8	26·0
M. . .	34·6	36·6	44·2	48·9	52·8	58·4	61·1	62·5	56·3	49·1	44·2	38·0	48·9	27·9
IS. . .	35·1	36·0	40·6	46·9	52·4	56·6	61·1	60·5	55·3	49·0	43·7	38·3	48·0	26·0
IS. . .	35·9	36·7	41·1	46·6	51·8	57·2	60·6	60·3	55·6	49·8	44·6	39·5	48·3	24·7
. . .	37·1	37·7	41·8	46·8	51·3	56·3	60·0	60·0	56·1	51·0	45·9	41·0	48·7	22·9
. . .	39·0	39·1	41·9	46·4	50·8	54·9	58·8	59·3	56·6	52·2	47·5	43·0	49·1	20·3
. . .	42·3	41·2	42·0	45·0	48·9	52·2	56·1	57·4	56·4	53·5	49·4	45·7	49·2	16·2
SOCK.														
n . .	36·8	38·6	41·1	45·3	51·2	57·2	59·7	59·1	55·2	47·5	42·5	37·4	47·6	22·9
. . .	37·1	38·2	40·4	45·5	51·8	57·6	60·3	59·7	56·3	49·5	43·9	39·0	48·3	23·2
IWELL.														
n . .	35·8	37·0	40·7	45·2	51·4	57·5	59·6	59·0	54·9	47·0	42·4	36·7	47·3	23·8
. . .	36·4	37·7	39·9	45·3	51·2	57·2	59·7	59·1	56·0	49·1	44·3	39·3	47·9	23·3
LLEY.														
n . .	37·8	39·5	40·6	45·3	50·2	56·9	60·0	59·1	55·2	46·9	41·6	37·3	47·5	22·7
. . .	38·8	39·2	40·5	45·0	50·5	56·7	59·6	58·9	55·3	*48·6*	43·1	38·9	*47·9*	20·8
LEYTON.														
n . .	35·7	37·3	41·7	46·6	51·5	57·4	60·3	60·3	57·0	49·1	44·0	38·9	48·3	24·6
. . .	41·3	40·9	41·6	45·0	49·4	54·1	57·7	58·2	57·1	53·6	48·8	44·7	49·4	17·3
STOFT.														
n . .	37·2	38·6	40·8	44·6	*50·2*	*56·3*	*60·0*	59·9	57·0	49·4	44·5	*39·0*	*48·1*	22·8
. . .	37·2	37·8	39·9	45·2	51·7	58·1	61·3	60·5	57·2	49·6	44·3	39·1	48·5	24·1
. . .	37·8	38·4	40·4	45·5	52·0	58·3	61·8	61·4	58·5	51·4	45·8	40·4	49·3	24·0
. . .	41·2	40·9	41·7	45·0	49·5	54·4	57·8	58·5	57·1	52·8	48·2	43·9	49·2	17·6

TABLE V.—MEAN TEMPERATURE OF THE AIR AND SOIL FOR THE PERIOD STATED IN TABLE I.—*continued.*

STATIONS.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.	Range.
ASPLEY GUISE.														
	°	°	°	°	°	°	°	°	°	°	°	°	°	°
Air, mean . .	35·8	37·8	40·9	45·6	51·6	57·8	60·6	59·8	55·7	47·4	42·4	37·1	47·7	24·8
,, 9 A.M. .	35·5	37·1	40·8	46·6	53·8	59·5	62·5	61·5	56·6	48·1	42·6	37·0	48·5	27·0
Soil, 3 ins. . .	35·5	37·1	39·9	46·6	55·0	62·2	64·7	62·5	57·1	48·1	42·3	*37·0*	*49·0*	29·2
,, 6 ins. . .	35·8	37·5	40·1	46·4	54·3	61·5	64·2	62·3	57·3	48·6	42·8	*37·5*	*49·0*	28·4
,, 1 ft. . .	36·0	37·7	40·3	46·2	53·7	60·8	63·7	62·1	57·3	48·9	43·2	38·0	49·0	27·7
,, 2 ft. . .	37·8	39·0	41·4	46·7	53·6	60·0	63·4	62·5	58·6	51·2	45·3	40·2	50·0	25·6
,, 4 ft. . .	40·5	40·5	41·6	45·4	50·4	55·8	59·4	60·0	57·9	53·1	47·9	43·4	49·7	19·5
BENNINGTON.														
Air, mean . .	34·7	37·9	42·3	47·1	51·9	58·8	60·9	60·4	56·3	47·9	42·6	38·7	48·3	26·2
Soil, 1 ft. . .	36·2	38·1	41·0	46·4	52·6	59·6	62·2	61·2	57·3	49·9	44·2	39·7	49·0	26·0
BERKHAMSTED.														
Air, mean . .	35·5	37·0	41·1	45·9	51·9	58·3	60·4	59·9	56·1	47·8	42·8	37·3	47·8	24·9
Soil, 1 ft. . .	35·9	37·4	40·4	47·0	54·4	60·8	63·4	62·3	58·2	50·2	44·4	38·6	49·4	27·[illegible]
,, 2 ft. . .	37·8	38·6	40·8	46·7	53·1	59·2	62·4	62·2	59·1	52·3	46·5	40·9	50·0	24·[illegible]
CAMDEN SQUARE.														
Air, mean . .	38·1	39·9	43·0	48·5	54·3	60·9	63·4	63·1	58·3	49·8	43·7	38·9	50·2	25·[illegible]
Soil, 1 ft. . .	38·3	38·9	40·7	45·9	52·3	58·7	62·1	61·7	57·5	50·2	44·4	39·9	49·2	23·[illegible]
REGENT'S PARK.														
Air, mean . .	37·5	39·2	42·2	47·3	53·7	59·9	62·6	61·6	57·4	48·9	44·2	39·0	49·5	25·1
Soil, 1 ft. . .	36·7	37·6	39·4	44·9	52·5	59·4	62·6	61·5	57·2	49·4	43·9	39·0	48·7	25·9
,, 4 ft. . .	40·3	39·8	40·2	43·4	48·6	54·7	59·2	60·2	58·3	53·3	47·9	43·5	49·1	20·4
GREENWICH.														
Air, mean . .	37·2	38·8	41·9	47·5	54·2	60·2	63·1	62·4	57·9	49·0	44·2	38·6	49·6	25·9
Soil, 3·2 ft. . .	41·3	*41·8*	*42·0*	46·1	51·7	57·9	61·8	62·2	60·1	54·6	49·4	44·5	*51·1*	20·9
NORWOOD.														
Air, mean . .	37·4	39·2	42·2	47·0	53·3	59·5	62·1	61·3	57·2	48·8	44·1	38·8	49·2	24·7
Soil, 1 ft. . .	37·3	38·5	40·5	45·9	52·7	59·1	62·4	61·6	57·8	50·1	44·6	39·5	49·2	25·1
ISLEWORTH.														
Air, mean . .	38·2	42·0	42·4	47·4	53·1	58·8	62·4	61·1	57·0	48·6	44·0	39·5	49·5	24·2
Soil, 1 ft. . .	38·5	40·2	41·7	46·6	53·7	59·6	63·2	62·0	57·7	50·1	44·0	39·7	49·7	24·7
,, 2 ft. . .	40·7	41·3	42·8	46·7	52·8	58·5	62·3	62·2	58·8	52·4	46·8	42·3	50·6	21·6
CROYDON.														
Air, mean . .	39·3	41·6	42·6	46·4	53·3	57·5	61·8	61·3	56·7	48·9	44·6	40·4	49·5	22·5
,, 9 A.M. . .	38·0	40·4	41·7	47·4	55·4	59·0	62·8	62·0	56·5	49·0	43·9	39·7	49·7	24·8
Soil, 6 ins. . .	38·8	39·6	40·8	45·7	54·1	59·4	63·2	61·9	56·9	49·2	43·7	39·5	49·4	24·4
,, 1 ft. . .	39·6	40·3	41·8	46·3	54·0	59·2	63·2	62·4	57·9	50·5	44·8	40·4	50·0	23·6
CARDIFF.														
Air, mean . .	40·9	42·0	42·4	47·6	52·5	58·3	61·0	60·2	56·4	48·8	45·0	40·6	49·6	20·4
Soil, 1 ft. . .	41·7	42·2	42·2	47·1	52·3	58·6	61·6	61·1	57·3	50·9	46·4	42·3	50·3	19·[illegible]
,, 4 ft. . .	45·8	45·0	44·7	46·3	49·2	53·2	56·3	57·7	56·8	54·1	50·8	47·6	50·6	13·[illegible]
MARLBOROUGH.														
Air, mean . .	36·8	38·6	40·5	*45·4*	*51·1*	*57·0*	59·4	58·6	54·6	46·7	42·4	37·6	*47·4*	22·[illegible]
,, 9 A.M. . .	35·9	37·4	40·2	46·3	53·1	59·0	61·7	60·7	56·0	46·8	42·0	37·0	48·0	25·[illegible]
Soil, 6 ins. . .	*37·3*	*38·8*	*40·4*	*45·9*	*53·2*	*59·6*	62·5	60·9	56·3	48·7	43·8	39·0	*48·9*	25·[illegible]
,, 1 ft. . .	38·3	*39·5*	41·3	46·6	53·7	60·0	62·7	*61·6*	*57·2*	49·8	*44·8*	*40·0*	*49·6*	24·[illegible]

TABLE V.—MEAN TEMPERATURE OF THE AIR AND SOIL FOR THE PERIOD STATED IN TABLE I.—*continued.*

STATIONS.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.	Range.
MARGATE.														
Air, mean . .	38·1°	38·7°	42·1°	46·4°	52·2°	58·0°	61·0°	61·8°	58·5°	50·1°	45·2°	39·6°	49·3°	23·7°
Soil, 1 ft. . .	39·2	39·3	41·4	47·0	53·5	59·7	*62·8*	62·6	59·3	51·4	46·7	41·4	*50·4*	23·6
„ 2 ft. . .	41·5	41·1	42·2	46·7	52·1	57·4	60·9	61·4	59·4	53·7	48·9	44·3	50·8	20·3
„ 4 ft. . .	44·3	43·4	43·4	46·1	50·0	54·1	57·3	58·9	58·4	55·2	51·2	47·5	50·8	15·5
TUNBRIDGE WELLS.														
Air, mean . .	35·9	38·6	42·4	47·1	52·5	58·7	60·6	60·0	56·9	48·6	43·4	38·0	48·5	24·7
Soil, 1 ft. . .	37·3	38·8	41·4	47·2	54·0	60·5	63·0	62·1	58·3	50·6	44·8	38·6	49·7	25·7
HARESTOCK.														
Air, mean . .	37·1	38·7	41·0	46·1	51·7	58·2	60·3	59·9	56·3	48·1	43·2	38·4	48·3	23·2
Soil, 1 ft. . .	37·9	*39·0*	*40·0*	45·3	51·6	58·0	60·9	60·4	57·1	50·2	45·1	40·3	*48·8*	23·0
„ 2 ft. . .	39·5	40·0	40·6	44·7	50·1	55·8	59·3	59·4	57·1	51·7	46·9	42·4	49·0	19·9
„ 4 ft. . .	42·8	42·1	41·9	44·0	47·6	52·0	55·6	56·9	56·4	53·5	49·7	45·9	49·0	15·0
SOUTHAMPTON.														
Air, mean . .	37·3	38·0	40·1	44·9	52·8	59·1	60·2	59·3	56·6	48·1	43·6	37·6	48·1	22·9
„ 9 A.M. . .	36·8	36·8	40·4	45·9	54·5	60·9	62·1	61·0	58·0	49·2	43·9	37·5	48·9	25·3
Soil, 3 ins. . .	36·8	37·0	39·8	46·2	55·0	61·8	63·4	61·6	57·5	48·7	44·3	38·8	49·2	26·6
„ 6 ins. . .	37·0	37·4	39·8	45·7	54·2	60·9	62·5	60·9	56·9	48·6	44·4	39·0	48·9	25·5
„ 1 ft. . .	38·8	39·4	41·2	46·7	54·2	60·1	62·0	61·0	57·8	50·8	46·6	41·6	50·0	23·2
„ 2 ft. . .	40·4	40·8	42·0	46·7	53·0	58·5	60·8	60·6	58·2	52·3	48·1	43·5	50·4	20·4
„ 4 ft. . .	42·9	42·6	42·7	45·6	50·1	54·7	57·7	58·3	57·0	53·4	49·7	46·2	50·1	15·7
BRIGHTON.														
Air, mean . .	38·5	40·3	45·2	50·1	54·5	60·4	63·0	62·7	59·4	51·8	46·5	42·5	51·2	24·5
Soil, 4 ft. . .	43·4	42·9	44·5	48·5	52·8	57·0	60·2	61·4	60·1	56·5	51·3	47·2	52·1	18·5
WORTHING.														
Air, mean . .	38·5	39·8	41·9	47·0	52·8	58·3	60·6	60·7	58·1	50·4	45·5	40·1	49·5	22·2
Soil, 1 ft. . .	39·1	40·2	42·3	48·1	54·8	60·6	63·1	62·7	59·3	51·9	46·5	41·2	50·8	24·0
STOWELL.														
Air, mean . .	37·0	37·8	40·8	46·2	51·7	57·7	59·6	59·0	55·9	47·5	43·3	38·5	47·9	22·6
Soil, 1 ft. . .	37·9	39·2	41·0	47·1	54·2	61·2	63·4	62·4	59·0	51·2	45·8	*40·9*	*50·3*	25·5
CULLOMPTON.														
Air, mean . .	39·0	40·4	41·3	45·8	51·7	57·4	60·3	59·3	55·5	48·6	44·8	40·1	48·7	21·3
Soil, 1 ft. . .	39·7	41·0	42·3	46·9	53·4	59·7	62·8	61·9	57·6	50·5	45·9	41·1	50·2	23·1
ROUSDON.														
Air, mean . .	38·0	38·5	41·2	45·8	51·0	56·9	58·5	58·4	55·8	49·0	44·7	40·3	48·2	20·5
Soil, 1 ft. . .	38·6	39·4	41·2	46·8	53·2	59·5	61·6	60·7	57·5	51·1	46·2	41·6	49·8	23·0
„ 2 ft. . .	40·6	41·0	41·9	46·5	52·0	57·3	60·1	59·9	57·9	53·1	48·3	44·0	50·2	19·5
„ 4 ft. . .	42·8	42·4	42·5	45·5	49·8	54·2	57·4	58·0	57·2	54·0	50·0	46·3	50·0	15·6
TAVISTOCK.														
Air, mean . .	38·1	39·9	44·9	47·6	54·3	59·8	60·7	58·9	57·0	48·2	45·2	42·1	49·7	22·6
„ 9 A.M. . .	37·4	39·3	45·1	48·6	56·3	61·9	62·2	60·5	59·1	49·2	46·0	41·9	50·6	24·8
Soil, 6 ins. . .	38·4	39·6	44·5	49·5	56·1	62·0	63·3	61·6	58·4	51·1	45·2	41·7	50·9	24·9
„ 1 ft. . .	39·6	40·3	44·9	49·7	56·3	62·0	63·5	62·1	59·1	52·0	46·4	42·7	51·5	23·9
BABBACOMBE.														
Air, mean . .	41·6	42·0	42·4	46·4	51·9	57·9	60·1	60·2	56·9	50·2	46·6	42·0	49·8	18·6
„ 9 A.M. . .	41·1	41·5	43·0	47·3	53·4	59·4	61·9	62·2	58·0	51·2	46·8	41·6	50·6	21·1
Soil, 6 ins. . .	40·5	41·6	42·7	48·3	55·0	61·1	63·3	62·9	59·0	51·7	47·0	41·9	51·2	22·8
„ 1 ft. . .	41·3	42·5	43·6	49·1	55·4	61·3	63·7	63·6	60·1	53·2	48·3	43·1	52·1	22·4

at 12 ins. the largest range is 0°·7 and at 22 ins. only 0°·3; but at these last two depths the curves seem somewhat irregular, and it is probable that a longer series would be necessary to establish satisfactory averages.

Mr. Marriott, in his paper above quoted, refers to a discussion by Mr. Symons of six years' observations at Regent's Park made three times a day—viz. at 9 a.m., 3 p.m., and 9 p.m.—in which very much larger differences were found. The July results showed "that the temperature of the soil, 3 ins. deep, rises from 64°·9 to 75° between 9 a.m. and 3 p.m., falls from 75° to 67°·2 by 9 p.m., and probably still lower during the night, rising again to 64°·9 by 9 a.m. next day. The 6 ins. thermometer shows similar changes, but to a lesser extent; and as the 9 p.m. temperature is 4°·9 above that at 9 a.m., it is evident that both the minimum and maximum temperatures occur considerably later in the day than at 3 ins. below the surface. The 1 ft. thermometer shows 2°·3 difference between 9 a.m. and 9 p.m., and an exactly intermediate reading at 3 p.m.; it is therefore probable that the soil at a depth of 1 ft. is coldest at 9 a.m. and hottest, not at midday, but at 9 p.m. At 2 ft. below the ground the temperature at the three observation hours only differs by 0°·1, being identical at 9 a.m. and 3 p.m., and 0°·1 colder at 9 p.m. The 4 ft. thermometer shows no difference whatever. In winter these daily ranges are of course very much smaller, in fact scarcely one-tenth of what they are in July."

From this it seems that at depths greater than 1 ft. the 9 a.m. temperature will be appreciably equal to the mean for the day throughout the year, but that at 1 ft. it will be slightly below the daily mean in summer, at any rate in England; and that at lesser depths these differences will be rather larger. In winter the difference will probably be of little consequence.

Comparing the mean values for the year, we find that in nearly all cases the temperature of the soil at a depth of 1 ft. is slightly higher than that of the air; the only exceptions to this rule are Norwood, where the two have the same temperature, and Regent's Park and Camden Square, where the soil is 0°·8 and 1°·0 respectively colder: these stations are all on the London Clay. On the other hand, the soil is warmer by more than 2° at three stations—Alnwick, Marlborough, and Stowell—which have a light to medium soil. In winter time, as pointed out by Mr. Marriott, the air and the soil at 1 ft. have about the same temperature, the soil being often a little warmer till about the end of January, after which, for the next two months, the air has a small advantage; but in the summer months the soil at this depth is generally warmer than the air, the difference exceeding 3° at several stations. The London stations are again an exception, at Camden Square the soil being as much as 1°·8 colder than the air in July; it is also slightly colder at Strelley, which has a strong soil; and at Southwell (medium soil) and Newton Reigny the differences are small.

It should, however, be remembered that, as pointed out above, the temperature of the soil at this depth at 9 a.m. in summer is rather lower than the mean for the day, so that, if this were allowed for, the temperature of the soil would be rather more above the mean temperature of the air at this season than the tables seem to indicate.

TABLE VI.—PARTICULARS OF SCOTCH STATIONS.

Station.	County.	Height above Sea.	Geological Formation.	Nature of Soil.	State as to Moisture.	Period employed in Table VII.[1] Years.	From	To
		ft.						
Sandwick	Orkneys	94	Devonian	Strong, rich black loam soil on pure clay subsoil	Drained, slopes gently to N.	20	1863	1885
Dunrobin Castle	Sutherland	9	Gneiss, lias, and conglomerate	Sandy loam resting on rough gravel	Naturally dry, never water-logged	26	1863	1892
Banchory	Kincardine	99	Metamorphic	...	...	5	1863	1868
Arbroath	Forfar	71	Devonian	Coarse gravel and sand, over which a layer of black earth, made ground	Quite dry, on a hill with sloping bank	26	1863	1892
Barry	,,	38	Devonian, intruded trap	Dark vegetable mould on fine yellow sand with pebbles	Dry	26	1863	1892
Ochtertyre	Perth	333	Devonian with trap dykes	Light sandy soil mixed with trap	Dry, on a sloping bank	15	1875	1892
Cairndow	Argyll	25	Metamorphic	...	...	7	1865	1872
Nookton	Fife	80	Coal Measures	Sandy	Dry	12	1863	1875
Deanston	Perth	100	Devonian	...	...	8	1866	1874
Poltalloch	Argyll	135	Metamorphic	Sandy loam, subsoil pure sand	Not water-logged, but saturated after heavy rains: wet district	27	1863	1892
Smeaton	Haddington	100	Basalt?	Heavy loam, subsoil yellow clay	Dry	27	1863	1892
East Linton	,,	90	Basalt?	Light, subsoil gravelly	Dry	21	1863	1886
Joppa	Edinburgh	20	Carboniferous limestone	...	...	6	1883	1889
Paisley, Coats Observatory	Renfrew	107	Carboniferous and glacial	Boulder clay	Dry	6	1887	1892
Thirlestane Castle	Berwick	558	Devonian	Clayey loam on till clay subsoil	Drained	17	1863	1880
Marchmont	,,	500	Carboniferous limestone	Red loam to 2 ft., subsoil wet and poor gritty stuff	Very dry	22	1867	1892
Auchendrane	Ayr	97	Devonian	...	...	9	1865	1874

[1] The records used extend over the seventeen years from July 1863 to June 1880, and the ten years 1883 to 1892, total twenty-seven years. The observations for the two and a half years from July 1880 to December 1882 have not been published. At most stations the returns are missing for a few months.

The above figures lead us naturally to a consideration as to how far the consistency of the soil may influence its temperature either on the mean for the year or at any particular season. With a view of elucidating this, I have selected the stations at which the soil appears to be undoubtedly strong, and also those at which it is undoubtedly light. I found seven in each category, viz. :—

Strong Soils.	Light Soils.
Rounton.	Southport.
Strelley.	Hodsock.
Camden Square.	Aspley Guise.
Regent's Park.	Bennington.
Norwood,	Margate.
Isleworth.	Harestock.
Worthing.	Southampton.

Comparing the mean values for the whole period for which the observations were available at each station (Table V.), the excess of the temperature of the soil at 1 ft. over the mean temperature of the air in each month was as follows :—

	Light Soils.	Strong Soils.
January	+0°·9	+0°·2
February	+0·3	−0·7
March	−0·7	−0·8
April	+0·2	−0·8
May	+1·1	+0·1
June	+1·2	+0·2
July	+1·6	+0·4
August	+1·2	+0·4
September	+1·1	+0·5
October	+1·9	+1·4
November	+1·5	+0·7
December	+1·6	+0·9
Year	+1·0	+0·2

From this we see that on the mean for the year the light soils are 1°·0 warmer than the air, while the strong ones are only 0°·2 warmer.

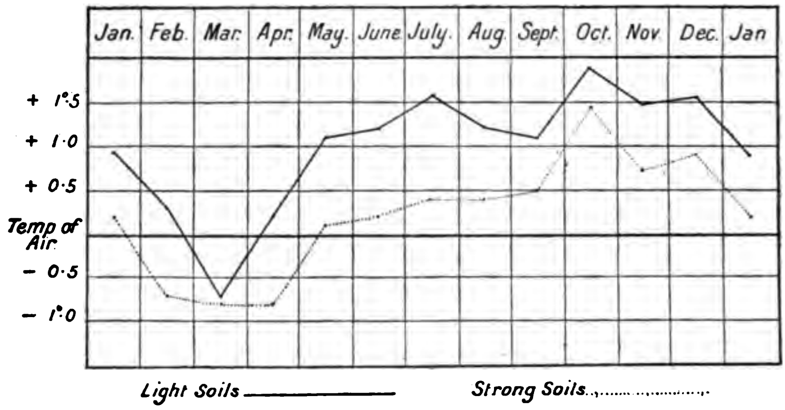


FIG. 1.—Difference of the Temperature of Light and Strong Soils from that of the Air.

The values are plotted in Fig. 1, from which we see that the two curves have very much the same shape, but that the light soils are com-

paratively the warmer throughout the year, except in March, when both are equally colder than the air; in each case the maximum excess occurs in October, amounting to 1°·9 in the case of the light soils, and to 1°·3 in the case of the heavy ones. It is important to note that the greatest differences are to be found between April and August, the season during which vegetation is most active.

Treating the Scotch stations in a similar way, I have compared six light soil stations (Dunrobin, Arbroath, Ochtertyre, Nookton, Poltalloch, and East Linton) with four heavy soil ones (Sandwick, Smeaton, Thirlestane, and Marchmont), and find that the differences are in the same direction, though not so large. Thus, on the mean of the year, the soil is 0°·7 warmer than the air in the case of the light soils, and 0°·5 warmer in the case of the heavy ones, and in July the corresponding figures are 1°·5 and 0°·8. It should, however, be mentioned that at one of the light soil stations (Arbroath) the soil seems for some reason to be abnormally cold, viz. 1°·5 colder than the air on the mean of the year, and more (instead of less) in July. If this station were excluded, the excess of soil temperature over the air at the others becomes 1°·1 on the mean of the year, and 2°·3 in July.

In both the English and Scotch series there are anomalies in the case of individual stations, which seems no more than we should reasonably expect, as undoubtedly many complicated factors must exist which should be taken into consideration as well as the actual consistency of the soil, and it will be only by taking an average of a number of stations that we can hope to eliminate these other causes.

It will be noticed that several of the strong soil stations (including those at which the soil is comparatively the coldest) are in the London district, and this suggests whether London smoke as well as London Clay may not be a contributing factor, or, in other words, whether, seeing that the excess of temperature of the soil above the air is most marked in summer time, the differences between stations may not be to some extent due to the varying duration of sunshine. In confirmation of this suggestion, we find that whereas in London the average duration of sunshine for the fifteen years 1881-95 was only 1240 hours, at Rothamsted (only a short distance from Aspley Guise, where the excess of soil temperature is unusually large) the duration is 1515 hours. This is also somewhat confirmed by the Nottinghamshire stations: at Hodsock the duration of sunshine is only 1247 hours, little more than in London, and though the soil is quite light it is comparatively colder than at most of the other light soil stations, while at Strelley the soil is distinctly cold, even for a strong soil station. Again, in the south of England the duration of sunshine is large: at Margate the average is 1503 hours, at Brighton 1706 hours, and at Southampton 1647 hours; and we find that not only at Margate and Southampton, where the soil is light, is the soil considerably warmer than the air, but that at Worthing, where the soil is described as loam and brick earth, the soil is much warmer than the air, especially in summer. On the other hand, at Harestock, not far from Southampton, the excess of soil temperature above that of the air is less than at most of the other light soil stations.

If the difference between the temperature of the soil and of the air is largely influenced by the duration of sunshine, we ought to find evidences

of such effect by comparing the results in years in which the amount sunshine differed considerably. Such a comparison is here made betw the summers of 1887 and 1888 at three stations, viz. Aspley Gui Regent's Park, and Hodsock. In 1887 the amount of sunshine recor at Aspley Guise and Hodsock during June, July, and August was j double of that in 1888—in London the proportion was slightly small September 1888 was rather the brightest in all cases. The excess of temperature of the soil at 1 ft. over that of the air for each of th months was as follows:—

		June.	July.	Aug.	Sept.
		°	°	°	°
Aspley Guise	1887	+3·3	+4·6	+3·6	+3·5
"	1888	+2·5	+3·2	+2·3	+2·1
Regent's Park	1887	−0·6	−0·6	−0·1	+2·1
"	1888	−0·7	−0·2	0·0	+0·1
Hodsock	1887	−0·3	−0·6	+1·1	+2·1
"	1888	+0·5	+0·8	+0·9	+2·3

Thus, at Aspley Guise the temperature of the soil was more ab that of the air in the bright year than in the dull one throughout the f months; at Regent's Park this difference did not show itself till Septemb and at Hodsock the two years were much alike.

At greater depths the mean temperature of the year is in nearly cases slightly higher than at 1 ft., but the difference is usually less t 1°. There is little difference between the means at 2 ft. and 4 ft., b on the whole, 2 ft. seems to be slightly warmer. Thus, taking fr Table V. the averages at the following seven stations at which observations have been taken at the three depths, viz. Newton Reig North Thoresby, Aspley Guise, Margate, Harestock, Southampton, Rousdon, we find that at 2 ft. the mean is 0°·5 higher than at 1 ft., that at 4 ft. it is only 0°·3 higher.

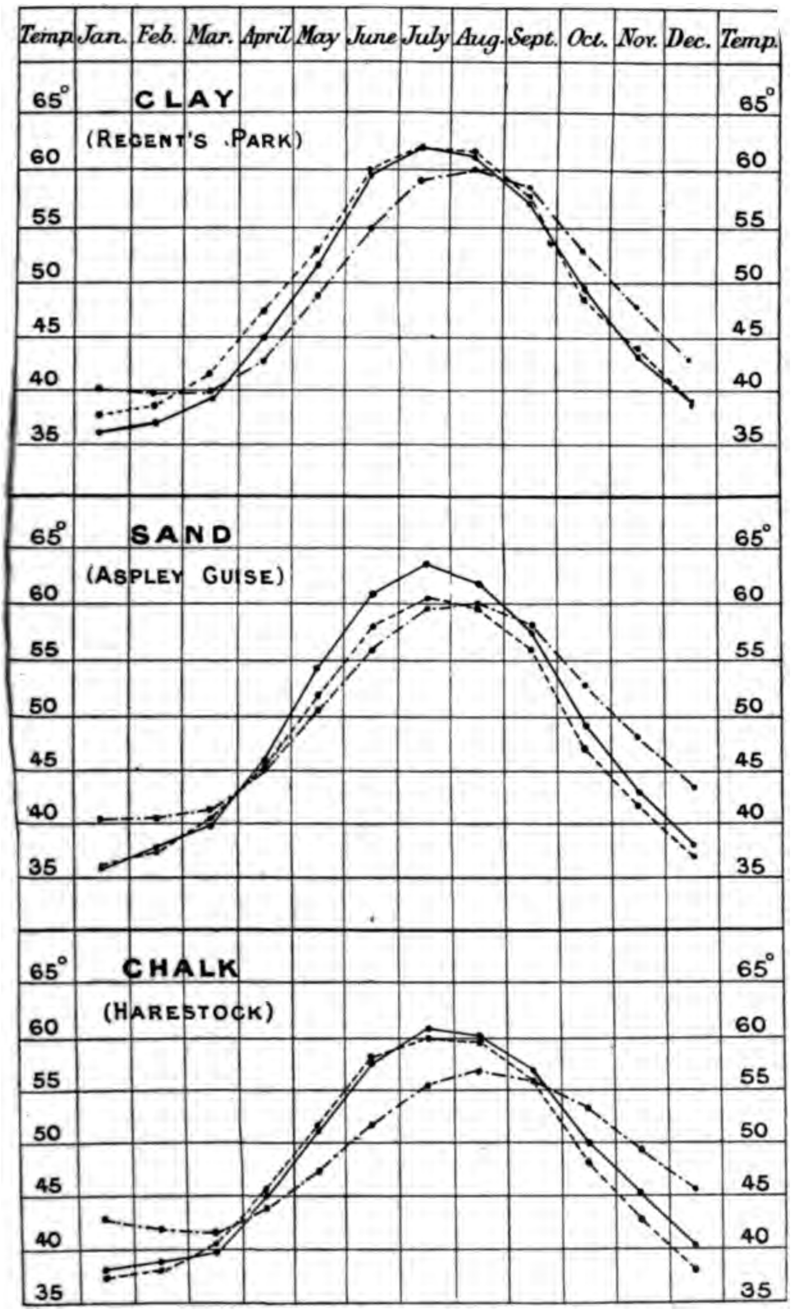
On plotting the monthly values at different depths for any station will be seen that the curves cross each other about the end of March again about the second week in September, at which periods the temperat of the soil is uniform to a depth of at least 4 ft.

At 1 ft. the maximum and minimum occur respectively in July January, as is the case with the mean temperature of the air; at 4 ft. time of the extremes has been retarded about one month, and they oc generally in August and February; while at Harestock at 6 ft., and Southport at 10 ft., the time has been retarded yet another month, they occur in September and March.

At Greenwich, at a depth of 12·8 ft., the extremes occur in Septem and early in April; and at twice this depth, 25·6 ft., the maximum occ at the end of November, and the minimum in June.

Mons. Angot, in his *Traité Élémentaire de Météorologie* recently publish enunciates the rule that "the retardation of the epoch of maxima minima is proportional to the depth"; and this appears to be in acco ance with the above statement.

In Fig. 2, which is reproduced from the Presidential Address Mr. E. Mawley (*Quarterly Journal*, vol. xxiv. p. 62), these curves are gi for three stations—Aspley Guise, Regent's Park, and Harestock— depths of 1 ft. and 4 ft., as well as for the mean temperature of the ai



Air Temperature .... - - - - - - - -
Earth Temperature at 1 foot deep .... ————
Earth Temperature at 4 feet deep ...... -.-.-.-

Fig. 2.—Mean Monthly Temperature of the Air and of the Soil at 1 foot and 4 feet deep, for the fourteen years 1883-96.

At a depth of 1 ft. the range between the warmest and the coldest month is in nearly all cases larger than in the air; Camden Square and Strelley being again prominent exceptions. As will be pointed out later, the rate at which the range decreases with increasing depth seems to depend partly on the nature of the soil; but in nearly all cases the range at 2 ft. is less than in the air (Aspley Guise and Lowestoft the only exceptions), while at 4 ft. the range is from 5°·5 to 8°·0 less than at 1 ft.

At Harestock (chalk), temperatures have also been recorded for some years at 6 ft., and the ranges at the different depths during the five years 1891-95 were as follows:—1 ft., 25°·6; 2 ft., 22°·6; 4 ft., 15°·9; 6 ft., 12°·4; but it should be noted that this lustrum was marked by larger differences between winter and summer temperatures than the rest of the period.

At Southport, readings have also been taken at a depth of 10 ft., and the following were the ranges at the different depths for the five years 1893-97,—1 ft., 24°·8; 4 ft., 18°·5; 10 ft., 10°·5. The soil here is light sand, but the water level is reached at a depth of less than 4 ft.[1]

Dr. Buchan, in his paper published in 1862, already quoted, came to the following conclusions, viz.: "that light loose soils are subject to a greater degree of frost near the surface than strong clay soils; but that, on the other hand, frosts do not penetrate so far down into light loams as into strong clay soils. The explanation is, that air, which is about the worst conductor of heat, fills the interstices of the light loose soils, and thus diminishes proportionately their conducting power." We may reasonably expect that the corresponding proposition will also be true, and that higher maxima will also be recorded near the surface in light soils, but that they will not penetrate to such great depths as in strong soils. If both these propositions are true, we may express them in another way by saying that under similar conditions the range of temperature will be largest near the surface in a light soil, but that it will decrease more rapidly with increasing depth than in a heavy soil.

[1] Mons. Angot, in his book already referred to, gives the following law as applicable to this decrease of range, viz.: "that the range of any oscillation decreases in geometrical progression as the depth increases in arithmetical progression." If we denote by a the range of the surface layer, then it follows from this rule that the range at a depth of n feet may be expressed by ar^n, where n is a coefficient peculiar to each station, and is doubtless a function of the conductivity of the soil. This value of r is easily calculated for any place at which the range is known at any two depths, and has been worked out for the following stations from the observations at depths of 1 and 4 ft.; it is, in fact, the cube root of the ratio of the ranges at these depths.

VALUES OF r.

Newton Reigny	·895	Cardiff	·868
Southport	·907	Margate	·869
Lowestoft	·901	Harestock	·867
Aspley Guise	·890	Southampton	·878
Regent's Park	·924	Rousdon	·879

The rule has been tested by calculating from these values of r the ranges at other depths and comparing these figures with the observed values, and is, on the whole, fairly well confirmed. Thus, at Newton Reigny the calculated range at depths of 3 ins., 2 ft., and 3 ft. respectively are 22°·3, 18°·6, and 16°·4, and a reference to Table V. shows that none of these differ by more than 0°·4 from the observed values. At other stations the agreement is not always quite so close, especially in some cases in the surface layers, which is probably due to the surface soil differing in character from the subsoil, as the formula can only be expected to hold good as long as the nature of the soil remains unchanged. The law also applies fairly well to the Greenwich observations down to the depth of 25·6 ft.

TABLE VII.—MEAN TEMPERATURE OF THE AIR AND SOIL FOR THE PERIOD STATED IN TABLE VI.

Station.	Jan.	Feb.	Mar.	Apr.	May.	June	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.	Range.
SANDWICK.	°	°	°	°	°	°	°	°	°	°	°	°	°	°
Air . . .	39·0	39·0	39·3	43·3	46·5	52·0	55·0	54·5	51·8	47·0	41·9	40·0	45·8	16·0
Soil, 3 ins. . .	37·7	38·1	39·7	44·8	48·6	53·5	55·6	55·6	52·3	47·0	41·0	39·4	46·1	17·9
,, 12 ins. .	38·2	38·4	39·0	42·9	46·7	50·7	53·4	53·8	51·7	47·5	42·2	40·0	45·4	15·6
,, 22 ins. .	40·0	40·0	40·1	42·7	45·9	49·3	52·2	53·2	52·1	48·6	44·5	41·8	45·9	13·2
[illegible]NROBIN CASTLE.														
Air . . .	38·1	39·0	39·9	44·3	48·2	53·1	56·1	55·6	52·0	46·7	41·9	38·5	46·1	18·0
Soil, 3 ins. . .	35·9	37·0	38·6	44·6	49·9	55·8	58·6	57·7	53·7	46·8	40·6	37·0	46·3	22·7
,, 10 ins. .	36·0	37·1	39·1	44·7	50·3	56·2	59·4	58·8	54·9	47·5	41·2	37·2	46·9	23·4
,, 22 ins. .	36·8	37·7	39·6	44·6	50·0	55·5	58·9	58·7	55·3	49·1	42·5	38·5	47·3	22·1
BANCHORY.														
Air . . .	35·2	36·7	38·0	44·4	48·7	54·6	55·4	54·2	52·1	45·8	40·8	39·4	45·4	20·2
Soil, 3 ins. . .	33·0	33·8	34·9	42·4	48·0	55·7	58·1	56·3	51·2	43·6	37·4	35·5	44·2	25·1
,, 12 ins. .	34·8	35·1	36·6	43·5	49·1	56·1	59·9	58·0	53·8	47·2	40·7	38·0	46·1	25·1
,, 22 ins. .	36·1	35·7	36·8	42·3	48·0	54·7	58·7	57·3	54·2	48·5	41·9	39·0	46·1	23·0
ARBROATH.														
Air . . .	37·8	38·9	39·9	44·8	49·0	55·2	58·4	57·2	53·4	47·3	41·5	37·7	46·8	20·7
Soil, 3 ins. . .	35·7	36·1	37·0	41·8	46·4	52·7	55·9	54·4	51·1	44·6	39·5	36·3	44·3	20·2
,, 12 ins. .	36·8	37·3	38·0	42·3	46·8	52·6	55·9	55·4	52·5	46·8	41·5	38·1	45·3	19·1
,, 22 ins. .	38·5	38·5	39·1	42·4	46·7	52·0	55·5	55·7	53·5	49·2	44·2	40·4	46·3	17·2
[illegible]RRY [FORFAR].														
Air . . .	37·2	38·7	40·0	44·9	49·5	55·7	58·7	57·5	53·8	47·1	41·3	37·4	46·8	21·5
Soil, 3 ins. . .	36·0	37·0	38·0	44·4	49·9	55·5	57·9	56·9	52·8	45·9	40·3	36·7	45·9	21·9
,, 12 ins. .	36·3	37·3	38·2	43·6	48·8	54·1	56·8	56·2	52·7	46·5	41·2	37·5	45·8	20·5
,, 18 ins. .	36·8	37·8	38·5	43·9	48·3	53·5	56·3	55·8	52·8	47·4	42·3	38·4	46·0	19·5
,, 22 ins. .	37·2	38·0	38·7	43·7	47·9	53·1	56·4	56·3	53·1	47·5	42·6	38·8	46·1	19·2
,, 36 ins. .	38·2	38·5	38·8	42·6	46·6	51·6	55·3	55·5	53·0	48·3	43·6	40·0	46·0	17·3
,, 48 ins. .	39·6	39·5	39·8	43·0	46·6	51·1	54·5	55·1	53·1	49·4	45·1	42·0	46·6	15·6
OCHTERTYRE.														
Air . . .	36·5	38·1	39·2	44·1	49·9	56·0	58·5	57·4	53·3	46·7	40·7	38·3	46·6	22·0
Soil, 3 ins. . .	35·9	36·4	38·0	44·6	52·1	59·0	61·2	59·3	54·6	47·2	40·9	36·6	47·1	25·3
,, 12 ins. .	36·9	37·1	38·9	44·8	51·6	58·1	61·0	59·8	56·0	49·2	43·1	38·3	47·9	24·1
,, 22 ins. .	37·9	37·9	39·0	43·6	49·4	55·2	58·6	58·4	55·9	50·5	44·6	40·1	47·6	20·7
CAIRNDOW.														
Air . . .	39·1	41·7	42·1	47·7	51·4	57·1	60·7	59·0	55·0	49·0	42·4	40·7	48·8	21·6
Soil, 3 ins. . .	36·5	39·0	38·6	44·6	49·6	55·3	58·7	57·4	53·6	47·5	40·2	38·5	46·6	22·2
,, 12 ins. .	37·4	39·7	39·9	45·6	50·3	54·9	58·6	57·7	54·6	48·7	42·1	39·7	47·4	21·2
NOOKTON.														
Air . . .	36·8	38·3	40·3	46·1	49·5	55·3	58·7	57·1	53·5	46·7	40·4	37·8	46·7	21·9
Soil, 3 ins. . .	36·1	37·0	39·2	45·8	50·4	56·2	58·8	57·6	53·8	47·1	40·4	37·0	46·6	22·7
,, 12 ins. .	37·2	38·3	40·5	46·7	51·1	56·2	59·5	58·8	55·6	49·4	42·6	39·2	47·9	22·3
,, 22 ins. .	38·1	38·6	40·4	45·6	49·9	54·3	57·5	57·8	55·3	50·1	43·8	40·2	47·6	19·7
DEANSTON.														
Air . . .	36·7	38·4	39·0	45·2	48·3	54·9	57·9	56·5	51·6	44·8	38·5	36·5	45·7	21·4
Soil, 3 ins. . .	37·4	38·8	39·2	45·2	50·7	57·9	60·5	57·8	52·5	45·2	39·1	38·0	46·9	23·1
,, 12 ins. .	38·0	39·6	40·6	45·9	50·7	57·8	61·6	59·6	54·4	47·8	41·1	38·8	48·0	23·6
,, 22 ins. .	36·8	37·7	39·0	43·9	48·9	55·9	59·5	58·5	54·1	47·2	41·3	37·9	46·7	22·7
POLTALLOCH.														
Air . . .	39·0	39·4	40·1	45·3	49·6	55·6	57·6	57·3	53·8	47·7	42·4	39·6	47·3	18·6
Soil, 3 ins. . .	37·8	38·1	39·1	45·1	51·1	57·7	60·0	58·7	54·1	47·4	41·5	38·7	47·4	22·2
,, 12 ins. .	38·2	38·7	39·9	45·4	51·3	57·6	60·5	59·7	55·4	48·9	43·0	39·6	48·2	22·3
,, 22 ins. .	38·7	39·0	39·9	44·9	50·6	56·6	60·1	59·8	56·1	50·1	44·1	40·3	48·3	21·4

TABLE VII.—MEAN TEMPERATURE OF THE AIR AND SOIL FOR THE PERIOD STATED IN TABLE VI.—*continued.*

STATIONS.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.	Range.
SMEATON.														
	°	°	°	°	°	°	°	°	°	°	°	°	°	°
Air . . .	37·1	38·3	39·8	45·3	50·3	56·7	59·3	57·6	53·5	46·4	40·6	37·3	46·8	22·2
Soil, 3 ins. . .	35·5	36·0	37·9	45·2	52·5	58·8	61·6	60·0	54·8	47·0	40·6	36·9	47·2	26·1
,, 12 ins. .	36·3	36·6	38·3	44·9	51·4	57·8	61·2	60·2	56·0	48·7	42·2	37·9	47·6	24·9
,, 22 ins. .	37·3	37·2	38·6	44·4	50·6	56·8	60·6	60·2	56·6	49·9	43·6	39·3	47·9	23·4
EAST LINTON.														
Air . . .	37·7	38·9	40·2	45·4	49·0	55·5	58·8	57·6	54·0	47·3	41·3	38·0	47·0	21·1
Soil, 3 ins. . .	36·2	36·6	37·9	43·8	49·4	56·3	59·7	57·9	53·1	46·5	40·3	37·3	46·2	23·5
,, 12 ins. .	38·3	38·9	40·0	45·7	51·0	57·3	61·0	60·0	55·7	49·5	43·2	39·8	48·4	22·7
,, 22 ins. .	38·6	38·6	39·5	43·9	48·8	54·8	58·7	58·5	55·4	50·7	44·1	40·3	47·7	20·1
JOPPA.														
Air . . .	39·2	38·7	40·3	44·4	49·6	54·5	58·4	57·4	54·1	47·8	42·3	38·7	47·1	19·7
Soil, 3 ins. . .	37·2	36·6	38·4	42·8	49·0	54·5	58·0	56·0	52·3	45·9	41·0	37·7	45·8	21·4
,, 12 ins. .	37·6	37·7	38·6	43·3	48·8	54·0	57·6	56·2	53·3	46·9	42·0	38·8	46·2	20·0
,, 22 ins. .	38·2	38·0	38·8	43·0	47·6	52·7	56·0	55·5	53·0	47·5	43·1	39·8	46·1	18·0
PAISLEY.														
Air . . .	39·6	39·5	40·1	44·8	52·1	57·4	58·4	57·6	54·9	48·9	42·8	38·8	47·9	19·6
Soil, 3 ins. . .	38·5	38·0	38·4	42·4	50·1	56·8	57·6	56·7	53·6	46·2	42·5	38·7	46·6	19·6
,, 12 ins. .	38·8	38·8	39·1	43·1	50·1	55·7	57·8	57·0	54·0	47·3	43·3	39·4	47·0	19·0
,, 22 ins. .	40·2	40·4	40·2	43·4	49·1	54·6	56·8	56·8	54·5	49·3	46·4	41·7	47·8	16·6
THIRLESTANE.														
Air . . .	34·4	36·3	38·1	44·0	47·7	54·4	57·2	55·6	51·5	44·9	38·2	35·2	44·8	22·8
Soil, 3 ins. . .	35·0	35·7	37·0	43·5	49·1	56·0	59·0	56·5	51·3	44·6	38·2	36·1	45·2	24·0
,, 12 ins. .	35·6	36·0	37·6	43·5	48·4	54·7	58·3	56·9	52·8	46·6	39·9	37·0	45·6	22·7
,, 22 ins. .	36·1	36·1	37·5	42·5	47·2	52·9	56·9	56·6	53·1	47·6	41·2	37·8	45·5	20·8
MARCHMONT.														
Air . . .	36·2	37·5	38·7	43·2	47·8	53·9	57·2	56·3	52·3	45·7	39·8	35·7	45·4	21·5
Soil, 3 ins. . .	35·1	35·8	37·2	42·6	49·2	56·2	59·5	57·9	52·5	44·6	38·7	35·5	45·4	24·4
,, 12 ins. .	36·1	36·8	38·3	43·0	48·9	55·0	59·1	58·0	53·7	46·6	40·6	36·7	46·1	23·0
,, 22 ins. .	37·3	37·7	38·6	42·7	48·0	53·8	57·6	57·6	54·3	47·9	42·2	38·4	46·3	20·3
AUCHENDRANE.														
Air . . .	39·1	41·4	41·5	46·7	49·2	55·6	58·8	57·3	54·0	47·6	41·8	40·3	47·8	19·7
Soil, 3 ins. . .	37·0	38·1	39·1	45·5	50·8	58·5	61·0	58·7	54·2	46·6	39·6	38·4	47·3	24·0
,, 12 ins. .	37·3	38·4	39·8	46·1	51·5	58·7	61·9	60·4	56·1	48·9	41·7	39·2	48·3	24·6
,, 22 ins. .	38·6	39·3	40·4	45·3	50·3	56·7	60·3	59·9	56·8	50·8	44·1	40·9	48·6	21·7

It will be interesting to see what light is thrown on these questions by the observations now available. For this inquiry I have used the stations where observations have been taken at both 1 ft. and 4 ft., which unfortunately are not very numerous, so that there are not many pairs of stations where the soil conditions present the required contrast, while climatic conditions are similar. Such a pair are Regent's Park and Aspley Guise, which are about 40 miles apart and have similar climatic conditions, except that, as already pointed out, Aspley Guise enjoys the most sunshine. At Regent's Park about 12 ins. of garden mould rest on a tenacious yellow clay, while at Aspley Guise after a few inches of vegetable mould there is light sand to a depth of 100 ft.

A comparison has been drawn between these two stations both as regards extreme temperatures and monthly means. In the first place, we may

ɔmpare the minima recorded during the three hardest frosts in the seven-ɜen years (see Table IX.), and we find that in 1881 at 1 ft. the tempera-ɪre fell at Aspley Guise to 27°·0, or 4°·6 lower than at Regent's Park, but that t 4 ft. Regent's Park was the colder by 2°·0. Much the same was the ɪse in 1891, but the differences were not so large; at 1 ft. Aspley Guise 'as colder by 1°·3, while at 4 ft. Regent's Park was colder by 1°·7. ɔuring the great frost in 1895, lower readings were recorded at Regent's 'ark at both depths; but while the difference at 1 ft. was only 0°·2, at ft. it was as much as 1°·4. Dealing in a similar way with maximum ɜmperatures, we find that the highest values were recorded in 1881 and 893. In the former year, at 1 ft., temperature rose 2°·0 higher at Aspley ɪuise than at Regent's Park, but at 4 ft. Regent's Park had the higher eading by 1°·1; in the latter, the differences were in the same direction, nd amounted to 2°·5 at 1 ft. and 0°·2 at 4 ft.

I have also taken out the highest and lowest temperature in each year, nd the average of these for the seventeen years at each station are as ɔllows (see Table X.):—

	1 ft. Max.	1 ft. Min.	1 ft. Range.	4 ft. Max.	4 ft. Min.	4 ft. Range.
	°	°	°	°	°	°
Aspley Guise. . .	69·1	32·1	37·0	61·5	38·6	22·9
Regent's Park. . .	66·7	32·7	34·0	61·5	37·7	23·8

Thus we see that while the extreme range in the year is on the average 3°·0 larger at the depth of 1 ft. at Aspley Guise than at Regent's Park, ɪt 4 ft. it is 0°·9 smaller.

Turning next to monthly means, we find similar results; thus in Jan-ɪary 1881 the soil was 1°·5 colder at Aspley Guise at a depth of 1 ft., ut at 4 ft. in February (which at this depth was colder than January) 'egent's Park was colder by 0°·7. In February 1895 the differences ere smaller; at 1 ft. both stations had the same temperature, and at ft. Regent's Park was colder by 0°·4. So for the summer months, in ɪly 1887 Aspley Guise was warmer than Regent's Park at a depth of ft. by 3°·3, but at 4 ft. in August this difference was reduced to 0°·1.

Finally, in the following table we have the mean temperature on the ɜrage of the seventeen years of the hottest and coldest months, viz. ly and January at 1 ft., August and February at 4 ft.

	1 ft. July.	1 ft. Jan.	1 ft. Range.	4 ft. August.	4 ft. Feb.	4 ft. Range.
	°	°	°	°	°	°
Aspley Guise .	63·7	36·0	27·7	60·0	40·5	19·5
Regent's Park .	62·6	36·7	25·9	60·2	39·8	20·4

that while the mean monthly range is 1°·8 larger at Aspley Guise at ., it is 0°·9 smaller at a depth of 4 ft.; or, to put it in another way, while range is 8°·2 smaller at a depth of 4 ft. than at 1 ft. at Aspley Guise, s only 5°·5 smaller at Regent's Park.

Comparing in a similar way Lowestoft, which has a sand and gravel (the uncertainty of the zero error here does not affect a comparison annual range), with Somerleyton, which is only a few miles distant, has a clay loam soil, for the three years 1894-96, we find that at westoft the mean monthly range falls from 24°·6 at 1 ft. to 18°·2 at ., a difference of 6°·4; while at Somerleyton the corresponding differ-e is only 4°·4, the range being 22°·1 at 1 ft. and 17°·7 at 4 ft. On

the other hand, if we compare Lowestoft with North Thoresby in Lincolnshire, which has a clay soil, we find that the rate of decrease of the range is the same at both places. For some reason, the range at Lowestoft seems to be maintained at an unusually large figure down to a depth of 2 ft., where it is in fact as large as at 1 ft.; below 2 ft. it decreases more rapidly than at North Thoresby.

Taking the South of England stations, we find that the rate of decrease of range from 1 ft. to 4 ft. at Margate and Harestock is the same (both these are in the chalk); so at Southampton, which has a light sandy soil, the range decreases at the same rate as at Harestock for the five years common to both series. Again, comparing Harestock with Rousdon, which is on a clayey gravel, for the ten years 1886-95, we find that the range falls off most rapidly on the chalk soil; it is largest at Harestock at 1 ft., and the same at both stations at 4 ft.

At Southport, observations have also been made at depths of 1 ft. and 4 ft., but there is no other station in the same district with which they can be compared. The soil here is pure blown sand, but the mean monthly range seems to decrease rather less rapidly than at most light soil stations in other districts (range at 4 ft., 6°·3 less than at 1 ft. for the five years of observation). It must, however, be noticed that the 4 ft. thermometer was generally just under the subsoil water line.

Comparisons have also been made between two pairs of the Scotch stations at depths of 12 ins. and 22 ins. In the case of East Linton, which has a sandy soil, the mean monthly range decreases from 22°·7 at 12 ins. to 20°·1 at 22 ins., a difference of 2°·6; while at Smeaton, quite close by, but with a clay soil, the decrease is from 24°·8 to 23°·1, or only 1°·7: these values are for twenty-one years at each station. Comparing in the same manner the records for Nookton (sandy) with Thirlestane (clay) for twelve and a half years, we have a decrease of 2°·6 at Nookton, and of 1°·7 at Thirlestane—the same figures as in the case of the other pair.

Down to a depth of 1 ft., the range of temperature of the soil seems to increase above the range of mean temperature of the air rather faster in light soils than in heavy ones. Thus, if we take the same two sets of seven English stations which have already been used (p. 252), we find that in the case of the heavy soils the mean monthly range of temperature of the soil at this depth is only 0°·1 greater than the corresponding figure for the mean temperature of the air, but in the case of the light soils it is 0°·6 greater.

Much the same applies to the Scotch stations. Adopting the same division as before, we find that in the case of the four heavy soils the range at 1 ft. is 0°·9 greater than in the air, but in the case of the six light soils it is 2°·1 greater.

The conclusion to be drawn from the discussion of this part of the subject seems undoubtedly to be that Dr. Buchan's proposition is confirmed, and that near the surface we may expect to find wider extremes of temperature in light soils than in strong ones; but that the heavier soils are better conductors of heat, and that consequently the extremes are propagated to greater depths in heavy soils than in light ones.

Fig. 3 represents the limitation of seasonal change with increasing depth at three stations—Aspley Guise, Regent's Park, and Harestock.

The thick line shows the limits of the mean temperature of the hottest and coldest months at each, and also of the mean temperature of the air; the finer prolongations show the limits of the extreme temperatures recorded during the period. The mean temperature at each depth is also shown.

The differences between the temperatures of light and strong soils, as judged by a comparison with the mean temperatures of the air at the various stations, are perhaps hardly as large as our preconceived

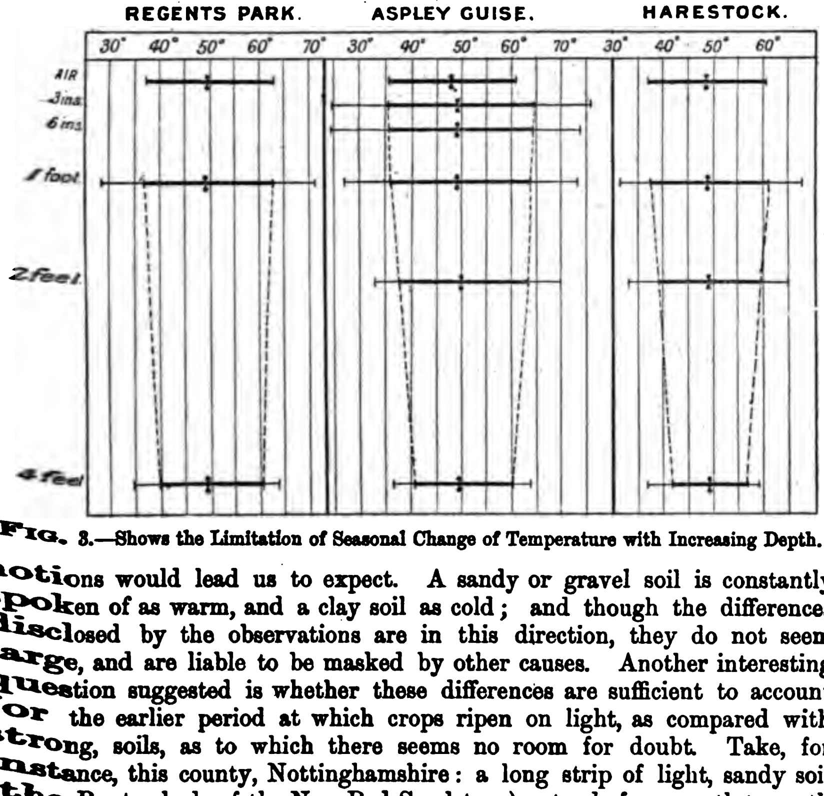


FIG. 3.—Shows the Limitation of Seasonal Change of Temperature with Increasing Depth.

notions would lead us to expect. A sandy or gravel soil is constantly spoken of as warm, and a clay soil as cold; and though the differences disclosed by the observations are in this direction, they do not seem large, and are liable to be masked by other causes. Another interesting question suggested is whether these differences are sufficient to account for the earlier period at which crops ripen on light, as compared with strong, soils, as to which there seems no room for doubt. Take, for instance, this county, Nottinghamshire: a long strip of light, sandy soil (the Bunter beds of the New Red Sandstone) extends from north to south for nearly the length of the county, bounded on the east by the strong clays of the Keuper, and on the west by the Permian marls and limestones, followed in their turn by the Coal Measure clays. The central strip of sand is undoubtedly a much earlier district than the stronger soils on either side of it. In order to get some measure of this, I have compared the dates of commencing harvest at Hodsock and on Mr. Edge's home farm at Strelley, and find that on the average of eleven years we began 9 days earlier on the sand than he did on the clay, though he is 27 miles farther south; the differences ranging from 3 days in 1884 to 17 days in 1892.

It seems not unlikely that the sites selected for the instruments in gardens may to some extent be responsible for rendering the conditions more uniform than if the thermometers had been placed in an ordinary

arable or pasture field, and this would be especially the case at depths down to 1 ft. In some cases the site is a lawn which at some former period has been levelled and has the character of "made" ground; in others, though a patch of grass surrounds the instruments, the soil has for many years been cultivated and manured, till the character of the original soil has been considerably modified. "Garden mould" is the term frequently used by the observers to describe the first few inches of the soil. The tendency of this will undoubtedly be towards uniformity, and the full effects of clay or sand, which may be exerting their influence on the crops in the adjoining fields, will be proportionately masked.

TABLE VIII.—Abstract of Observations made at Six Stations during July 1867. The Mean is that of 12 Observations Daily between 6 a.m. and 10 p.m.

Depth.	Sandwick.	Dunrobin.	Braemar.	Feddinch Mains.	Nookton.	Thirlestane.
3 Inches.						
Mean of 12 observations . . .	55°·6	58°·4	54°·5	56°·3	58°·6	59°·8
Mean at 9 a.m.	53·9	56·9	53·0	55·1	56·6	57·2
Difference between warmest and coldest hour	4·3	3·5	4·2	4·5	4·9	8·5
12 Inches.						
Mean of 12 observations . . .	53·4	57·1	52·2	54·5	56·8	56·4
Mean at 9 a.m.	53·4	57·2	52·4	54·3	56·7	56·5
Difference between warmest and coldest hour	0·2	0·3	0·3	0·7	0·6	0·5
22 Inches.						
Mean of 12 observations . . .	51·3	56·3	51·4	53·9	55·7	55·2
Mean at 9 a.m.	51·2	56·3	51·5	54·0	55·7	55·3
Difference between warmest and coldest hour	0·3	0·1	0·3	0·2	0·1	0·1

Hitherto the comparison has been between the temperature of the soil and the mean temperature of the air; however, two months may have the same mean temperature but very different daily extremes. To see if any connection could be traced between such differences and the soil temperature, a comparison has been made between a number of pairs of months at Hodsock having similar mean temperature, but a good deal of difference in the daily range. The tendency seems to be that in the colder months the minimum temperatures have the largest effect, and in the warmer months the maximum ones. Or, to put this in another way, if we compare two months with about the same mean temperature, but one of which has a larger daily range, then in winter time we shall expect to find this larger range accompanied by a lower temperature of the soil and in summer by a higher one. There are certainly exceptions to this rule, but this seems to be the general tendency. For instance, comparing the months of March in 1893 and 1897, the mean temperature in the former year was rather the higher,—45°·1 against 44°·5,—but the range was much larger and the nights consequently colder, and the soil temperature at 1 ft. was nearly 1° lower, viz. 41°·7 as against 42°·6. On the other hand, in July 1885 and 1886 the mean temperature was almost identical, but

the mean maximum temperature was 1°·2 higher in the former year and the soil was 1°·0 warmer; and under similar circumstances in July 1889 as compared with 1890 the soil was 2°·0 warmer. The explanation would seem to be that in winter the hour of observation is soon after the time of occurrence of the minimum temperature of the air, and the long winter night has a preponderating effect; whereas in summer the sun has had more time before 9 a.m. to warm the soil, and the shorter night has been less able to counteract the higher temperature of the day before. In the case of March 1893 and 1897 already mentioned, a comparison was also made at several stations at which the soil temperature had been observed at depths of 2 ft. and 4 ft. as well as of 1 ft., and it was found that in 1893, in which month the minima were lower, though the mean temperature was higher, the soil was colder at all these depths in all cases.

TABLE IX. (A).—HIGHEST AND LOWEST READINGS RECORDED IN CERTAIN YEARS.

STATION.	Maximum.						Minimum.								
	1 ft.		2 ft.		4 ft.		1 ft.			2 ft.			4 ft.		
	1881.	1893.	1881.	1893.	1881.	1893.	1881.	1891.	1895.	1881.	1891.	1895.	1881.	1891.	1895.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
Alnwick . .	66·0	...	64·0	...	...	...	35·0	...	...	39·0	...	...	...	...	...
Newton Reigny	...	...	...	...	...	...	...	33·9	...	...	35·9	...	...	38·0	...
Rounton . .	...	64·5	...	...	...	...	...	33·5	32·0	...	...	...	...	...	...
Bolton . .	...	65·0	...	63·1	...	...	...	32·8	31·0	...	34·1	33·2	...	...	...
North Thoresby	...	66·7	...	64·1	...	59·9	...	...	32·2	...	...	34·8	...	...	38·4
Hodsock . .	...	65·9	...	...	...	...	...	32·3	32·2	...	...	...	...	...	...
Southwell .	...	65·1	...	...	...	...	...	32·1	32·0	...	...	...	...	...	...
Somerleyton .	...	...	...	...	...	60·5	...	...	33·0	...	...	...	...	...	37·4
Aspley Guise .	73·2	71·5	69·2	70·0	61·6	63·8	27·0	29·2	28·4	33·2	33·4	32·4	37·5	36·7	36·2
Bennington .	...	69·3	...	...	...	...	...	32·1	32·0	...	...	...	...	...	...
Berkhamsted .	...	71·4	...	68·1	...	...	...	30·4	30·6	...	33·4	32·9	...	...	...
Regent's Park .	71·2	69·0	...	...	62·7	64·0	31·6	30·5	28·2	...	...	...	35·5	35·0	34·8
Norwood . .	69·5	73·2	...	...	...	...	33·1	32·2	32·1	...	...	...	...	...	...
Isleworth . .	71·0	...	67·8	...	...	...	31·2	...	...	34·9	...	...	...	...	...
Croydon . .	71·0	...	...	...	...	...	33·0	...	...	...	...	...	...	...	...
Marlborough .	69·0	70·6	...	...	...	...	...	32·6	31·0	...	...	...	...	...	...
Margate . .	...	69·8	...	65·0	...	61·2	...	33·2	32·6	...	36·4	35·8	...	40·1	39·9
Tunbridge Wells	...	68·6	...	...	...	...	...	31·7	31·9	...	...	...	...	...	...
Harestock .	...	67·4	...	64·9	...	59·2	...	32·4	31·7	...	33·8	34·2	...	38·8	38·3
Southampton .	68·5	...	...	...	...	...	34·3	33·8	...	...	36·1	...	...	39·0	...
Brighton . .	...	...	...	...	...	63·4	...	...	...	...	...	...	...	...	38·1
Worthing .	...	...	...	...	...	...	...	32·4	32·8	...	...	...	...	...	...
Stowell . .	...	69·8	...	...	...	...	...	31·8	30·3	...	...	...	...	...	...
Cullompton .	69·7	...	...	...	...	...	33·0	...	...	...	...	...	...	...	...
Rousdon . .	...	68·0	...	63·1	...	60·7	...	32·8	31·7	...	36·1	35·5	...	38·8	38·1
Tavistock .	...	72·8	...	...	...	...	...	...	33·4	...	...	...	...	...	...
Babbacombe .	68·7	...	...	...	...	...	34·8	34·5	...	...	...	...	...	...	...

Other factors which seem likely to have an influence on the temperature of the soil are the slope of the ground where the instruments are placed, its aspect and exposure to the sunshine. The rainfall too seems likely to have an effect, carrying down with it, as it soaks into the ground, its own temperature, which may or may not be the same as that of the air, depending, among other things, on the season of the year: this effect will also be modified by the degree of permeability of the soil. In fact,

as in so many other meteorological phenomena, the ultimate effect is modified by so many contributing causes that it becomes a matter of difficulty to distinguish the influence of any one particular cause.

The *Meteorological Record* gives, in addition to the mean temperatures, the maxima and minima in each month, and the highest and lowest in each year have been extracted. An inspection of these values showed that the highest readings occurred in 1881 and 1893, and the lowest in 1881, 1891, and 1895. In Table IX. (A) the readings at the different stations are given for these years at depths of 1 ft., 2 ft., and 4 ft.; and in Table IX. (B) at depths of 3 ins. and 6 ins. In each case in which the observations have extended over the whole period this table includes the extremes observed; but in some cases, where one or more of the years is missing, higher or lower readings have been recorded than those given. For instance, the record at Berkhamsted does not go back to 1881, a year which had the lowest minimum at the neighbouring station of Aspley Guise, and the lowest given for Berkhamsted in the table is 30°·4 in 1891, but it fell a little lower in 1893, viz. to 30°·3. In this way, lower readings than those given in the table for some stations were recorded in 1886, 1887, 1888, 1892, and 1893, and higher readings in 1886, 1887, and 1897.

TABLE IX. (B).—Highest and Lowest Readings recorded in Certain Years.

Station.	Maximum.				Minimum.					
	3 ins.		6 ins.		3 ins.			6 ins.		
	1881.	1893.	1881.	1893.	1881.	1891.	1895.	1881.	1891.	1895.
	°	°	°	°	°	°	°	°	°	°
Newton Reigny	...	...	...	...	...	30·8	...	...	...	...
North Thoresby	...	70·0	...	69·0	...	...	28·4	...	...	30·8
Bolton	...	...	...	65·6	...	...	...	...	...	27·4
Aspley Guise	75·9	73·3	73·2	71·9	24·7	27·2	26·6	24·5	28·4	27·3
Croydon	...	...	71·0	..	...	...	...	31·4	...	...
Marlborough	...	...	71·0	68·0	...	...	...	...	30·1	28·0
Margate	...	...	...	72·0	...	...	...	...	...	31·7
Southampton	...	...	...	...	...	26·2	...	...	27·5	...
Tavistock	...	...	...	74·4	...	...	...	...	...	32·1
Babbacombe	...	...	...	...	...	...	...	...	33·1	...

The table shows that down to a depth of 1 ft. the ground is liable to be frozen occasionally in most parts of England, but that at this depth it is only at a few places that readings below 30° are to be expected. At Aspley Guise it fell below this figure in each of the three years given, and also in 1893, the lowest of all being 27°·0 in 1881. The only other reading below 30° was 28°·2 at Regent's Park in 1895. At a considerable proportion of the stations, however, frost has not yet been recorded at this depth.

At lesser depths the minima have been still lower, the lowest being again at Aspley Guise in 1881, viz. 24°·7 at 3 ins., and 24°·5 at 6 ins. In 1891 Southampton had the lowest, and in 1895 Bolton was close behind Aspley Guise.

At 2 ft. there is no record of a frost, the lowest being 32°·4 at Aspley Guise in 1895 (31°·9 was returned from Lowestoft, but subsequent

investigation threw doubt on the accuracy of the reading). At 4 ft. the lowest records come from Regent's Park, where in 1895 it fell to 34°·8; but at most places 38° seems to be about the lowest to be expected.

Turning next to the maxima, we again find the shallow thermometers at Aspley Guise at the top of the list. At 3 ins. the temperature reached 75°·9 in 1881, and at 6 ins. 73°·2 in the same year, but this was surpassed by 74°·4 at Tavistock in 1893. At 1 ft. 73°·2 was recorded at Aspley Guise in 1881, and a similar reading at Norwood in 1893, but readings above 70° are not common, and have only occurred at a few stations round London and in the south of England; in the north, about 66° seems to be the highest to be expected. At 2 ft. 70° has been reached once, viz. at Aspley Guise in 1893, but at several places 64° has not been exceeded. At 4 ft., as in the case of the minima, we find the extreme at Regent's Park, viz. 64°·0; but at some stations the maximum has not reached 60°. There seems to be a wider difference between the maxima at different stations than between the minima.

For all stations at which the observations have extended over at least fifteen years, the average of the maxima and minima in each year have been calculated, and the result is given in Table X.

TABLE X.—AVERAGE YEARLY MAXIMA AND MINIMA.

STATION.	3 ins.		6 ins.		1 ft.		2 ft.		4 ft.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
	°	°	°	°	°	°	°	°	°	°
Rounton	...	...	...	...	62·3	34·2	...	...	...	...
Hodsock	...	...	...	...	63·8	34·5	...	...	...	...
Aspley Guise	70·9	30·3	69·7	31·1	69·1	32·1	66·9	35·0	61·5	38·6
Regent's Park	...	...	...	...	66·7	32·7	...	...	61·5	37·7
Norwood	...	...	...	...	66·4	33·7	...	...	...	...
Marlborough	...	...	67·2	32·8	67·0	34·4	...	...	...	...
Harestock	...	...	...	...	64·3	34·1	61·4	36·5	57·6	40·4
Worthing	...	...	...	...	66·5	35·1	...	...	...	...

It is not suggested that this by any means exhausts the information which these observations are capable of yielding, and it is to be hoped that the publication of the figures may induce some more competent person to turn his attention to the subject.

DISCUSSION.

Mr. W. MARRIOTT said that until the Royal Meteorological Society took up the subject of soil temperature, the question had received but scanty consideration from meteorologists in general; and he thought the Society could fairly be designated the pioneer of this branch of the science—certainly so far as Great Britain was concerned. During the early years little or no attention was paid to the errors of the instruments, but in more recent years he had regularly tested the thermometers at the Society's stations. In the case of Lowestoft an Regent's Park the thermometers were enclosed in long tubes buried in the ground, and could not be readily taken out for verification. Mr. Marriott then showed lantern slides of some of the Society's stations which were mentioned in

the paper, and described their aspect, characteristics, etc., as well as the methods adopted by different observers in combating difficulties which arose in connection with the observations. He also exhibited slides showing differences between the 1 ft. earth temperature and the temperature of the air, between the 1 ft. and 2 ft., and between the 1 ft. and 4 ft., for the months of January and July, for the period covered by the paper.

Mr. E. MAWLEY said that the results obtained by Mr. Mellish were of much value, and would form an excellent foundation for further work in the same direction. The first question which required attention was as to the best position in which to place earth thermometers in order to obtain comparable results. As compared with air temperatures, those of the ground appeared to be little influenced by warm and cold currents, but to be greatly affected by the amount of sunshine during the daytime and the cooling effects of radiation to the sky on clear nights. Consequently, in order to obtain the best results, it seemed to him that the spot selected for an earth thermometer should be almost as carefully chosen as for a sunshine recorder. In order to show the variety of influences likely to affect soil temperature, he might instance his own station at Berkhamsted, and that of Mr. Mellish at Hodsock. According to Table III. (B) the mean temperature of the air for the years 1886-90 was precisely the same at both stations ; but at 1 ft. deep the mean temperature of the soil, Table III. (A), for the same period was 1° higher at Berkhamsted than at Hodsock. No doubt the principal reason for this difference was the greater duration of clear sunshine at Berkhamsted than at Hodsock. But might it not also in some measure be due to other causes, such as the lawn at Berkhamsted being on a rather rapid slope facing south, while that at Hodsock was on level ground ? The exposure, as regards freedom from trees, etc., might be more satisfactory at one station than at the other. Then the grass on the lawn at Berkhamsted was no doubt more frequently burnt up during the summer months than at the more northern stations. In fact, for the lesser depths, he began to doubt whether a lawn was, after all, the best place on which to place an earth thermometer, the character of the grass differing greatly on different soils, and turf for lawns being so often laid on made ground. He would add emphasis to Mr. Mellish's remarks as to the usual hour of observation, 9 a.m., not being calculated to give the best results. But, as this was the most convenient time for the majority of observers, care should be taken that the exposure should be as complete as possible, and particularly towards the east, so that none of the early morning sunshine be lost. He could not understand the author's statement on page 246 that "at the depths of 12 ins. and 22 ins., the difference between the 9 a.m. values and the mean for the day are small and of no consequence," and yet a little later on he refers to Mr. Symons's investigations which showed the 9 a.m. temperature at 1 ft. deep to be generally the minimum for the preceding 24 hours. The difference given in the paper between the temperature of light and heavy soils was certainly less than might have been expected, considering the earlier growth of crops on the former. He thought that in addition to the slightly higher mean temperature of the light soils, the more rapid changes from warm to cold and from cold to warm on such soils had a more stimulating effect on vegetation than the more gradual changes on the heavier soils.

Mr. A. BREWIN remarked that it seemed from the paper that frosts at 1 ft. were not of common occurrence, and at 2 ft. there was no record of a temperature below 32°. In the great frost of 1895 engineers found themselves face to face with the question as to what depth the water-pipes should be laid so as to escape freezing, and he believed that the ultimate result was that 3 ft. was assigned as the depth at which it was desirable they should be laid.

Mr. R. LATHAM regarded the information contained in the paper as being o

considerable value. The temperature of the ground was, no doubt, one of the most important factors in considering the question of public health, and, hitherto, had been one of the questions which had been almost entirely neglected. From observations he had been making with regard to the hygrometric condition of the soil, he was convinced that the plague at Bombay, Hong Kong, and other places, might be ascribed to the influence of malaria, or exhalations from the soil, and these exhalations from the soil were, like the vapour of water, expelled from the soil by reason of the difference between the temperature of the soil and the dew-point of the air. With high temperature of the soil and low dew-point, vapours and malaria escape from the soil, that is, the power at work to expel malaria is the difference between the vapour tension due to the temperature of the soil and the vapour tension for the time being due to temperature of the dew-point of the air, subject, however, to modifications, having regard to the movement of the air.

Having regard to the importance of this question, he considered that it was imperative that the observations of underground temperatures should be largely increased, and that strict uniformity ought to be insisted upon as to the mode and depth at which the temperature should be taken. It would be seen, for example, that the records at Greenwich Observatory, which are recorded in French measurements, do not accord with the observations which have been made by the Society's observers; that at all places there ought to be some standard depth for observations to be carried on, and he thought that 30 ins. would be a suitable depth for such purposes. Observers might then increase the number of observations at various depths.

The best mode of taking observations is by means of water-tight tubes driven into the ground to the requisite depth, and by means of thermometers encased within glass tubes, the bulbs of which are surrounded with steatite or ground cork so as to render them very slow in recording. They could be drawn from even considerable depths and read without any alteration in temperature taking place. These instruments are capable of being verified with regard to their accuracy at any time, which is not the case with instruments in which the bulb of the instrument may be many feet below the surface, and the stem of the instrument divided for reading at the surface.

With reference to the point which Mr. Brewin has raised with regard to the freezing of water in pipes, it was a fact that water-pipes laid in certain districts at a depth of 2 ft. were found to be frozen in the frost of February 1895. This could not be ascribed alone to the effect of the frost at that particular depth; but the freezing depended very much upon the temperature of the water at the point at which the water originally entered the pipes; that is, the water flowing from a surface stream might be absolutely at the freezing-point and even below it, as he had known examples of water remaining liquid at a point below freezing, which when agitated froze to a solid mass. Hence the water entering from a very cold source, on movement would be liable to freeze at a depth where the earth was about the temperature of freezing-point; whereas water entering these mains, such as the chalk water supply, with a temperature of probably 20° above that of freezing, such mains would remain unfrozen, although laid at the same depth as those supplied from a surface source. In his judgment, it was desirable that the mains should be laid 3 ft. below the surface, and even deeper if the cost could be afforded, as depths of the mains not only prevented freezing in winter, but it lowered the temperature of the water in summer time; and he was certainly convinced that if a public water supply could be kept at a lower temperature in the summer time than had hitherto been the case, it would have an enormous influence in diminishing the rate of mortality from summer diarrhœa, especially among infants.

He had himself taken observations at various depths in the ground, varying

from 6 ins. to 50 ft. At this latter depth, however, there was very little variation. It should also be borne in mind with regard to these ground temperatures, that, in tropical countries like India, and in the case of Bombay, the ground temperature is in excess of the temperature of the air; hence the polluted soil at such a high temperature has a very marked influence in allowing malaria to escape and exercise its noxious properties in the inhabited districts, especially at night time, when there is a greater difference between the temperature of the soil and that of the air.

Mr. R. H. Curtis wished to emphasize what had already been said with reference to the effect of insolation upon the temperature of the soil. A proper "exposure" for an earth thermometer involved the selection of a spot upon which the sun could shine without interruption from sunrise till sunset, and he questioned whether this condition had been secured at many of the places for which results had been quoted in the paper. At Camden Square, for example, he thought it very probable that the direct sun rays were cut off from the soil for a considerable part of each day; and if that were so, he thought it would fully account for the comparatively low mean temperature at 1 ft. obtained there. In a similar manner, districts which from local causes receive a relatively small amount of sunshine, might be expected to exhibit one result of that fact in a relatively low temperature of the soil; and he suggested that the low mean temperatures quoted for Hodsock and Strelley might be due to the effect of the large masses of smoke emitted from the neighbourhood of Sheffield and other places to the westward, which, drifting towards them, might to some extent interfere not only with the duration, but also with the intensity, of the sunshine experienced at those stations. In the ten years 1881-90 Geldeston registered nearly 32 per cent more sunshine than Hodsock; and, if earth temperatures are observed at the former place, it would be interesting to see whether or not the mean temperature there showed a corresponding excess over the mean air temperature. In the same way there was no difficulty in understanding how a station situated on a slope with a full south aspect should get more out of the sun's rays than another situated on a slope facing north, the result being shown in a higher soil temperature, especially at slight depths. Free exposure to wind, by which the effect of terrestrial radiation would often be modified, was another important point to secure. With reference to the covering of the ground, he thought it the better plan to leave the ground bare. Grass was apt to modify the result by its length, and also by its colour and condition in dry seasons; and if watering were resorted to, it in its turn would be likely to influence the soil temperature through the effect of evaporation. With reference to Dr. Buchan's values for the mean soil temperature of the day, it should be remembered that the period from 10 p.m. to 6 a.m., during which there were no observations, was the period during which terrestrial radiation was most active, and it was important to know how that fact had been allowed for before accepting his figures as entirely satisfactory.

Mr. G. J. Symons said that it was disheartening what small circumstances would upset the continuity of the records. As he commenced making observations long before the Stevenson thermometer-screen was brought out, he began with a Glaisher pattern; and in order to ensure rigorous comparability, he had used it for more than forty years. He was therefore rather surprised to see the Camden Square returns in the table. He had recently thrown down the garden wall south-east of his soil thermometers, and perhaps by so doing had allowed more sunshine to reach their position than was formerly possible. He thought that the conditions Mr. Mawley would lay down with reference to "made soils" would be extremely hard on unfortunate Londoners, who are wholly dependent on such soils, especially for shallow depths. He believed that little had been done with regard to soil-temperature observations until

this Society interested itself in the development of this particular branch of meteorological observations. Mr. Latham seemed rather disappointed with the progress in this country, but he (Mr. Symons) thought that we had every reason to congratulate ourselves upon our position with regard to this subject, as the consideration given to it on the Continent and in America was extremely small, and it was only at the largest observatories that soil temperature observations were taken. With reference to the question of the freezing of the water in pipes at depths where thermometrical statistics show frost never penetrated, Mr. Symons agreed with Mr. Latham that it was partly due to the low temperature of the water on entering the pipes. He instanced an occasion when the River Thames at Molesey was completely frozen over within half a mile of the intake of one of the London Water Companies. The water was pumped into the Company's pipes at a temperature of 32°·6. He thought that the actual freezing was largely due to the fact that in London during the last few years there had been a great multiplication of fire-hydrants, with connecting pipes from the main at a depth only a few inches from the pavement. These recurred at frequent intervals, and in his opinion conducted the severe frost downwards to the main. Mr. Symons regarded the paper as a very valuable one, and was very glad that Mr. Mellish had taken up the subject.

Mr. J. Hopkinson inquired if Mr. Mellish had taken into consideration the disparity between the records of the different sunshine recorders, the indications of the Jordan Photographic Recorder being usually in excess of those of the Campbell-Stokes pattern. Mr. Mawley's statement of the effect of the southern aspect of his station at Berkhamsted, in increasing the range of temperature, afforded an explanation of the differences between his own observations at St. Albans and those of Mr. Mawley which had long puzzled him. He would suggest that a series of observations should be made on the opposite or northern slope of the valley, so that a comparison might be instituted. He considered Mr. Mellish's communication to be the most valuable he had yet heard on the subject of soil temperature.

Mr. R. Inwards thought it was important to fix upon the best form of instrument for the systematic observation of earth temperature, especially if that could be shown to have any relation to the Public Health. It seemed to him that in an iron tube only partially closed, it would be impossible to avoid interchange of air taking place when the earth temperature was warmer than that of the outside atmosphere, but whether this would cause any important difference in the readings, he could not say.

Mr. B. Latham remarked that he had made experiments with reference to the matter of convection inside a tube. The tubes he had used were about 2 ins. in diameter, so that if there was any liability to circulation round the instrument, it was likely to take place in such a tube; but he found that exactly the same result was obtained by having a number of thermometers at different depths in the same tube as compared with the observations taken in separate tubes at the same depths, showing there was little or no convection that would affect the temperature of the ground, and that with a deep tube several observations could be taken in the same tube with considerable accuracy,—in fact the only difficulty was regarding the reading of the instruments. With instruments which take at least 20 minutes to get the observation, owing to the protection of the bulbs with a non-conducting material, observations become very much simplified, as it is only necessary that these should be read once a day in order to get correct results as to what might be the state of the ground temperature from day to day.

Mr. W. H. Dines said he thought there must be some slight conduction of heat along the iron pipe which formed the case for the thermometer, but it seemed to have been shown to be too small to be of any consequence. It seemed

to him to follow from this that the theory that water-mains froze in consequence of the conducting power of the metal connections must be abandoned.

Mr. E. E. Dymond did not think that the heat at the surface would be in any way communicated to the instrument in the tube, but would be dissipated effectually before reaching the thermometer.

Mr. W. Marriott said that the instruments employed at the Society's stations were uniform in pattern. The instructions for the use of the earth thermometer, as given in the *Hints to Observers* (4th edition), p. 14, were:—

"The most convenient instrument for ascertaining the temperature of the soil is that known as 'Symons's Earth Thermometer.' This consists of a sluggish thermometer mounted in a short weighted stick attached to a strong chain, and of a stout iron pipe which is drawn out at the bottom to a point and driven into the earth to any required depth. The thermometer is lowered into the tube and the top closed by a cap. If only one thermometer be used, the bulb should be lowered to the depth of 1 ft. below the surface; but if more than one be employed the usual depths are 6 ins., 1 ft., 2 ft., 3 ft., and 4 ft. The tubes should be inserted in the soil below short grass in a well-exposed position. When snow has fallen, it should not be swept away from the ground round the earth thermometer, but left to melt in the same manner as the snow in the neighbourhood."

The thermometers were taken up, at the time of the inspection of the stations, for verification, which was of great importance in ensuring accuracy, by detecting changes that might have occurred since the previous examination. For instance, it was characteristic of new thermometers to read too high, while if a spirit thermometer were used the error would probably be in the other direction. If an observer possessed but one thermometer, he (Mr. Marriott) recommended 1 ft. as the most suitable depth; if he possessed two thermometers, then the 1 ft. and 4 ft., and if fortunate enough to have three thermometers he then recommended 1 ft., 2 ft., and 4 ft. The most general depth with the Society's observers was 1 ft., and after that in order of popularity came 4 ft. and 2 ft. He was glad Mr. Mellish had been able to extract such valuable results from the data published in the *Meteorological Record*.

Mr. H. Mellish, in reply, said with regard to what Mr. Mawley had said respecting the power of the grass in southern districts compared with that in the north in absorbing more heat from the sunshine, that he thought the grass differed less than any other crop, and was therefore more suitable for observations of soil temperature. The ordinary fallow would in time become grown over with rubbish, etc., and be far from a desirable condition under which to make observations. In reply to Mr. Hopkinson, he had made no distinction whatever between the patterns of sunshine recorders when comparing the results in respect of sunshine, but he understood the result of the latest comparison was that the Campbell-Stokes registered more sunshine than the Jordan Photographic pattern, which was in opposition to Mr. Hopkinson's views. It was important that the instruments should be so verified at regular intervals, as it was disheartening, where this had been neglected, to find that after perhaps having observations extending over a period of several years, an error of considerable magnitude had arisen that would affect the results seriously, and which might have been determined and applied had due observance been made of this important point. He thought that the conditions under which water-pipes were laid in London were scarcely comparable with those under which ordinary observations of soil temperature were made, as it was probable that London paving would be a better conductor of heat than the loose soil in which thermometers were generally exposed. He considered the woodwork in which the stem of the thermometer was placed was sufficient to prevent any circulation of the air inside the tube affecting the readings of the instrument.

PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

March 15, 1899.

Ordinary Meeting.

FRANCIS CAMPBELL BAYARD, LL.M., President, in the Chair.

TOWSON WILLIAM RUNDELL, 25 Castle Street, Liverpool; and
JOHN ROBERT WILLIAMS, M.B., Bryn Hyfrid, Penmaenmawr,
were balloted for and duly elected Fellows of the Society.

The following communications were read:—

"THE PROLONGED DEFICIENCY OF RAIN IN 1897 AND 1898." By FREDERICK JOHN BRODIE, F.R.Met.Soc. (p. 181).

"THE CLIMATE OF JERSEY." By the Rev. H. W. YORKE, M.A. (p. 203).

April 19, 1899.

Ordinary Meeting.

FRANCIS CAMPBELL BAYARD, LL.M., President, in the Chair.

WILLIAM HENRY BUTLIN, B.A., 39 East Park Parade, Northampton, was balloted for and duly elected a Fellow of the Society.

The following communication was read:—

"SOIL TEMPERATURE." By HENRY MELLISH, J.P., F.R.Met.Soc. (p. 238).

CORRESPONDENCE AND NOTES.

Deep-Earth Temperatures at Harestock and Southport.—Mr. Mellish, in his paper on "Soil Temperature" (p. 238), has discussed the observations received by the Society down to the depth of 4 ft. It may be interesting to supplement these by some observations at greater depths.

Harestock.—Col. H. S. Knight, at the Observatory, Harestock, near Winchester, has taken daily readings of thermometers at depths of 10 ft., 20 ft., and 30 ft., since 1893. The monthly means for the 6 years 1893-98 are given in Table I. Harestock is on the Downs, at a height of 300 ft. above sea-level; the soil is chalk.

The following is a description of Col. Knight's deep-earth thermometers. The case with its thermometer (the cylindrical bulb of which rests about half an inch above the perforated plug at its lower extremity) is fitted to travel to its position in the soil in a square-sided tube of teak wood, which stands 4 ins. above the surface of the ground to prevent water flowing into it, and extends perpendicularly into the earth as far as the square portion of the thermometer case. The cylindrical portion of the latter passes below the teak tube into a hole in which it exactly fits, and thus the thermometer acquires the true temperature at which it rests in the soil. When raised to the surface to be read, the portion below the shutter remains in the teak tube; the brush and fur trimmings prevent air currents in the tube. For the same purpose, plugs and cotton waste fill the upper end of the tube, which are removed before raising

the thermometer by its brass chain, which passes over a wheel on a post. This chain should have a mark on it to show when the thermometer case is about to touch the bottom of the hole. Also the top of the tube is covered with a wooden box having a sloping top, and this is covered with a waterproof apron of painted canvas to keep out wet.

TABLE I.—*Monthly Mean Temperatures of the Soil at Harestock*, 1893-98.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
10 Ft.													
1893	45·40	43·80	43·72	44·28	45·48	47·22	49·09	50·90	52·30	52·64	52·16	50·72	48·14
1894	49·07	47·74	47·07	46·75	47·33	48·16	49·52	51·22	52·37	52·60	52·23	51·23	49·61
1895	49·65	47·92	46·21	45·54	46·10	47·48	49·23	50·99	52·32	53·03	52·46	51·25	49·35
1896	49·85	48·89	47·83	47·57	47·95	49·03	50·74	52·37	53·25	*53·62*	52·82	51·02	50·41
1897	49·15	47·77	46·60	46·69	47·10	48·06	49·83	51·27	52·48	52·74	52·72	51·71	49·68
1898	50·24	49·22	48·37	47·62	47·72	48·60	50·07	51·68	52·94	53·56	53·25	52·30	50·46
20 Ft.													
1893	...	...	46·20	46·73	47·11	47·34	47·56	48·07	48·68	49·30	49·84	50·17	...
1894	50·21	50·02	49·70	49·35	49·06	48·91	48·92	49·11	49·48	49·91	50·29	50·53	49·62
1895	50·57	50·40	50·04	49·52	49·00	48·62	48·54	48·75	49·16	49·65	50·09	50·31	49·55
1896	50·38	50·22	49·97	49·60	49·34	49·19	49·23	49·48	49·92	50·39	50·79	50·97	49·96
1897	50·88	50·56	50·16	49·68	49·34	49·15	48·92	49·11	49·51	50·00	50·31	*50·75*	49·86
1898	51·24	51·07	50·81	50·52	50·21	49·97	49·90	50·03	50·35	50·77	51·16	51·45	50·62
30 Ft.													
1893	...	...	48·01	48·36	48·47	48·52	48·56	48·64	48·73	48·87	49·04	49·23	...
1894	49·42	49·56	49·62	49·63	49·54	49·46	49·39	49·34	49·34	49·39	49·49	49·61	49·48
1895	49·73	49·81	49·83	49·79	49·67	*49·70*	*49·60*	*49·55*	49·55	49·50	49·55	49·65	*49·66*
1896	49·78	49·88	49·92	49·93	49·90	49·82	49·75	49·71	49·71	49·79	49·90	50·03	49·84
1897	50·17	50·26	50·28	50·24	50·16	50·05	49·79	49·71	49·67	*49·76*	49·88	49·98	50·00
1898	50·11	50·20	50·23	50·27	50·21	50·14	50·07	50·00	49·99	50·00	50·08	*50·25*	50·13

At 10 ft. the range of temperature during the period was 10°·15; the highest reading being 53°·75, and the lowest 43°·60.

At 20 ft. the range of temperature was 3°·02; the highest reading being 51°·53, and the lowest 48°·51.

At 30 ft. the range of temperature was 0°·98; the highest reading being 50°·30, and the lowest 49°·32.

Col. Knight, for a part of the period, has also been taking daily readings of a thermometer at 70 ft. below the surface. The extreme range of temperature at this depth is less than 0°·10.

TABLE II.—*Monthly Mean Temperatures of the Soil at Southport*, 1893-98.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
10 Ft.													
1893	45·82	44·16	44·20	45·00	47·07	49·98	52·93	55·06	56·06	55·11	53·09	50·27	[illegible]
1894	48·02	46·63	45·82	46·30	47·76	49·49	51·99	54·10	54·60	53·86	52·17	50·14	[illegible]
1895	47·87	45·20	43·24	44·00	46·28	49·15	52·13	54·01	55·06	54·80	52·13	49·87	[illegible]
1896	47·69	46·54	46·00	46·46	48·33	50·98	53·65	55·27	55·63	54·59	51·63	48·91	[illegible]
1897	46·67	44·80	44·66	45·39	46·81	49·34	52·12	54·52	55·19	54·26	52·54	50·49	[illegible]
1898	46·76	46·33	45·48	45·85	47·76	50·43	53·55	55·52	56·44	55·46	53·31	50·56	[illegible]

Southport.—Mr. J. Baxendell has had readings taken of a thermometer at a depth of 10 ft. below the surface, in Hesketh Park, Southport, for the 6 years

1893-98. The monthly means are given in Table II. The soil is sand, and the height 21 ft. above sea-level. The range of temperature is greater than at Harestock. The thermometer is suspended by a chain in an iron tube, sealed at the lower end, and closed above the grass by a copper cap.

The Queen and the Weather.—It is not generally known that Her Majesty keeps a daily account of what the weather is like in her personal diary, but such is the case. Before the Queen retires to rest she copies from the special daily report forwarded to her from the Royal gardens at Windsor, where observations are made for the purpose by an expert among the Queen's gardeners. At the end of the month a special summary is also made out for Her Majesty, and the weather of the corresponding period in the previous year set side by side with it.—*Slough, Eton, and Windsor Observer.*

Loss of Life and of Property by Lightning.—The U.S. Weather Bureau has recently published a pamphlet entitled, *Lightning and the Electricity of the Air*, which is in two parts. Part I., which is by Mr. A. E. M'Adie, deals with the electrification of the atmosphere and the best methods of protecting life and property from lightning stroke, being a revision of a former bulletin (see *Quarterly Journal*, vol. xx. p. 273). Part II., which is by Mr. A. J. Henry, gives statistics of actual losses of life and property, including live stock in the fields, sustained in the United States during 1898.

Mr. Henry gives the following figures showing the total number of deaths by lightning in the United States during the 9 years 1890-98 :—

Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
0	4	36	122	345	678	738	496	153	35	6	3	2616

The author gives the number of deaths by lightning during the 3 years 1896, 1897, and 1898, and also the ratio of deaths in a million living, and classed under (1) persons engaged in outdoor pursuits; (2) rural population; and (3) total population. The districts showing the greatest proportion of fatal cases are the Missouri Valley, the Plains, and the Rocky Mountain and Plateau regions. It must be pointed out, however, that while the states of Montana, Wyoming, and Colorado contain a relatively small agricultural population, the proportion of fatal cases to the total population is 21 in a million—an unusually high rate.

Mr. Henry also goes into the question of the kind of trees struck by lightning. As, however, the observations in the United States for the year 1898 are not very numerous, he refers to the observations conducted by the overseers of forestry stations scattered throughout an area of about 45,000 acres in the Kingdom of Lippe, Germany. The percentage of the various species of trees of which the forest is composed is approximately as follows :—beech, 70 per cent.; oak, 11 per cent; pines, 13 per cent; firs, 6 per cent.

Number of Trees struck by Lightning.

Variety.	1879.	1880.	1881.	1882.	1883.	1884.	1885.	1890.	Total.
Oak	17	45	11	9	4	40	27	6	159
Beech	7	4	1	1	...	6	2	...	21
Pine	6	3	1	...	...	4	3	3	20
Fir	9	11	...	...	...	23	11	5	59
Birch	...	1	...	...	...	2	1	...	4
Larch	...	2	...	...	...	1	4	...	7
Ash	1	1	...	...	...	2	1	...	5

If the liability of the beech to lightning stroke be considered as 1, we obtain for the remaining principal varieties the following values :—

Liability to Lightning Stroke of the Oak, Pine, and Fir (Beech = 1).

Variety.	1879.	1880.	1881.	1882.	1883.	1884.	1885.	1890.
Beech . .	1·0	1·0	1·0	1·0	...	1·0	1·0	†
Oak . .	15·5	71·6	70·0	57·3	*	42·4	85·9	...
Pine . .	4·6	4·0	5·4	...	...	3·6	8·1	...
Fir . .	15·0	32·1	...	...	...	44·7	64·2	...

* Only oaks struck. † No beeches struck.

The above figures seem to show that the liability of the oak is always many times greater than that of the beech, and that it varies considerably from year to year.

Wave or Billow Clouds.—In the *U.S. Monthly Weather Review* for February 1899, Mr. A. J. Henry contributes reproductions of six photographs which he took at Washington of "Alto-Cumulus Rolls,"—four on November 23, 1898, and two on January 27, 1899. These show a remarkably perfect type of wave or billow clouds, parallel bands or ridges, separated by a small space of clear sky, as a furrow separates the rows of grain in a field.

The formation of billow clouds has been explained by various persons, *e.g.* Prof. Cleveland Abbe, Dr. W. von Bezold, Prof. H. von Helmholtz, and the late Rev. W. Clement Ley.

Mr. Henry says that, so far as observed, wave clouds have no particular significance, in the United States at least; although Dr. Kassner, of Berlin, is of opinion that in many cases they are an indication of precipitation.

RECENT PUBLICATIONS.

Las Nubes en el Archipélago Filipino. Por el P. José Algué, S.J. 4to[illegible] 26 pp. 1899.

It is satisfactory to find that, notwithstanding the recent war between th[illegible] United States and Spain, the Observatory at Manila has apparently escape[illegible] injury, and that the authorities have been able to continue their meteorologic[illegible] observations and to publish them.

The mean heights of the various forms of cloud during three periods of th[illegible] day for half-yearly periods were as follows:—

Form of Cloud.	April to September.							October to March.						
	8 a.m. to 12.		12 to 4 p.m.		4 to 8 p.m.			8 a.m. to 12		12 to 4 p.m.		4 to 8 p.m.		
	Mean height.	No. of Obs.	Mean height.	No. of Obs.	Mean height.	No. of Obs.	Mean.	Mean height.	No. of Obs.	Mean height.	No. of Obs.	Mean height.	No. of Obs.	Mean.
	ft.		ft.		ft.		ft.	ft.		ft.		ft.		ft.
Cirrus . .	35034	100	37535	16	37011	29	36527	36761	45	36694	7	31317	13	348[illegible]
Cirro-Stratus .	37117	16	51885	1	38641	3	42648	34518	14	42223	4	37806	3	381[illegible]
Cirro-Cumulus .	21632	44	19779	11	25747	10	22387	18236	21	18956	1	26011	6	210[illegible]
Alto-Stratus .	7586	1	15615	2	19137	3	14113	...	...	...	...	12790	1	...
Alto-Cumulus .	17270	11	18812	11	20170	4	18724	16015	23	13731	2	15906	7	152[illegible]
Strato-Cumulus	6546	9	...	...	5926	9	6236	7726	2	...	...	7509	5	76[illegible]
Nimbus . .	5086	3	...	...	3983	2	4535	4064	7	5337	2	5242	14	48[illegible]
Cumulus . .	5316	64	6352	7	6403	20	6024	5887	86	5996	18	6036	59	59[illegible]
Cumulo-Nimbus	17014	23	32239	4	14273	17	21176	10687	10	6913	6	13266	15	102[illegible]
Stratus . .	3758	4	3127	3	3922	2	3493	...	...	...	...	...	...	...

This work is a discussion of the observations made before the war at the Manila Observatory on the altitude and motion of clouds for the fourteen months June 1, 1896 to July 31, 1897, which were carried out in accordance with the recommendation of the International Meteorological Conference. A description is given of various forms of nephoscopes, and also of the method adopted at Manila for carrying out the observations.

Meteorologische Zeitschrift. Redigirt von Dr. J. HANN und Dr. G. HELLMANN. April—June 1899. 4to.

The principle articles are :—" Die Taifune vom 9 und 29 September 1897 " : von Dr. P. Bergholz (13 pp.). This is a paper based on the report by the Rev. Aloys Froc, of Zi-Ka-Wei ; and it differs from previous discussions of typhoons because, fortunately, a considerable number of Richard's barographs were on board vessels in the China seas at the time. This has rendered it possible to show the rate of barometer fall and rise. The two typhoons were of very different character.—" Die jährlichen Niederschlagsmengen auf den Meeren " : von A. Supan (4 pp.). This is a reprint from Petermann's *Geogr. Mittheilungen*, and Dr. Supan endeavours to give a representation of the distribution of rain at sea. He quotes Dr. Black's work *Ocean Rainfall*, but deals with more copious material. As regards quantity, he does not allude to the difficulty of securing an unexceptional exposure when the ship is under sail.—" Ein Normal-barometer" : von K. R. Koch (5 pp.). Dr. Koch, being dissatisfied with the discordances between the indications of the standard barometers of the chief meteorological observatories in Europe, has set to work to devise an instrument which shall meet all requirements. The mercury is distilled and redistilled several times, the vacuum chamber is large, and traces of air or moisture in it are withdrawn by a Sprengel's pump. The "attached" thermometers are two in number, and their bulbs are actually inserted into the barometer tube. The instrument is of the siphon form. For further details we must refer to the paper. The vacuum chamber is in constant connection with a tube packed with anhydrous phosphoric acid, and the vacuum can always be tested by means of a Hittorf's tube.—" Einige Ergebnisse der meteorologischen Beobachtungen am Observatorium Vallot auf dem Montblanc (4358 m.)" : von Dr. J. Hann (6 pp.). This is a brief notice of vol. iii. of Mons. J. Vallot's publication. The first gives a paper on the daily range of pressure at three stations, viz. Chamounix, the Grands Mullets, and Bosses (his own station), where he gives readings both of an aneroid and a mercurial barometer showing remarkable discrepancies. As to the range of temperature, the maximum and minimum both occur from an hour to an hour and a half earlier than at Chamounix. There are also interesting observations on the changes of density of snow and ice with age, carried on in the tunnel bored in the ice, and it appears that it takes 14 or 15 years to convert fresh-fallen snow into actual glacier ice. The amount of precipitation on the top of Mont Blanc is estimated at 0·6 m. (nearly 24 inches).—" Ueber verschiedene Entstehungsarten und Erscheinungsformen des Föhns" : von R. Billwiller (12 pp.). This paper leads off with a note on the etymology of the word "Föhn," which is shown to be almost certainly a corruption of "Favonius," as in some dialects on the southern slopes of the Alps, as at Bergell and Castasegna, the wind is called "Favougn," and the Romans recognised Favonius as a wind which caused snow to disappear. Dr. Billwiller deals with the Föhn first on the north side, then on the south side, of the Alps. Then he treats of its simultaneous appearance on both sides. He also shows that occasionally Föhn winds, *i.e.* hot dry winds, come out of an anticyclone, and are not perceived at the regular Föhn localities, such as Meiringen or Bludenz. A notable instance of this was the anticyclone of

November 28, 1897, when Föhn conditions were felt all over the flatter portion of Switzerland from the south-west up to the lake of Constance. Dr. Billwiller shows that the Föhn is not the continuation of the Sirocco, for very frequently there is but a small precipitation on the side of the Alps on which the air is supposed to ascend.—"Ueber die Bewölkung in Europa an Cyklonen—und Anticyklonen—Tagen": von Dr. C. Kassner (16 pp.). This is a comparison of the amount of cloud reported on each of three successive days at the three hours of 8 a.m., 2 p.m., and 8 p.m. Only five stations are taken: Bodö, Christiania, Budapest, Pawlowsk, and Tiflis. At the two latter stations the hours are 7 a.m., 1 p.m., and 9 p.m. In each case the actual principal day is taken, and one on each side of it. The figures are worked out with great elaboration, and the results are such as might reasonably be expected. There is more cloud with cyclones than with anticyclones, but all the stations do not agree in the small particulars as to which of the three days has the most cloud. In several cases Tiflis forms an exception.—"Erscheinungen des Erdlichts 1895-1899": von J. Maurer (4 pp.). This is an account of a peculiar phosphorescence of the atmosphere at night in the absence of moon and starlight, which has been rather frequently observed on the Alps; distant peaks being clearly seen, especially from the Rigi.

Proceedings of the Convention of Weather Bureau Officials held at Omaha, Nebr., October 13–14, 1898. U.S. Department of Agriculture. Weather Bureau. Bulletin, No. 24. 8vo. 1899. 183 pp.

Conventions of Weather Bureau officials have occasionally been held, but the subjects discussed have been restricted to the climate and crop features of the service. The deliberations of this Convention were of wider scope, covering practically the entire range of work of the Bureau, and the attendance was more than double that of any previous meeting. This report contains many papers of exceptional merit, which should be of interest and value not only to the employees of the Weather Bureau, but also to voluntary observers.

Symons's Monthly Meteorological Magazine. April—June 1899. 8vo.

The principal articles are:—"Winter Minima on British Mountain Tops" (5 pp.).—"Negretti & Zambra's Self-Recording Rain-Gauge" (2 pp.). The new self-recording rain-gauge is very simple and efficient, and is of very moderate price.—"Dr. Hellmann's Rainfall Map of Silesia" (2 pp.).—"Unprecedented Frost in the United States in February 1899" (3 pp.). On February 10 the weather in London was abnormally warm, the temperature being as high as 64°·8. This was in striking contrast to that on the other side of the Atlantic, for on the 12th and 13th the intensity of the frost in the south and south-east of the United States was equally unprecedented, the temperature being down to 7° at New Orleans on the Gulf of Mexico. This was 8° below the previous lowest recorded temperature.—"On a Recent Recurrence in Weather—a Lunar or 30-day Period," by H. H. Clayton (2 pp.).

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EAN TEMPERATURE OF THE SURFACE WATERS OF E SEA ROUND THE BRITISH COASTS, AND ITS RE-TION TO THE MEAN TEMPERATURE OF THE AIR.

By H. N. DICKSON, F.R.S.E., F.R.G.S.

[Read May 17, 1899.]

; efforts have been made, from time to time, to investigate the distribution of temperature in the surface waters of the sea ie British coasts, and to ascertain the precise extent to which vements influence the temperature of the air of these islands. ilts of such efforts have hitherto been somewhat inconclusive, ecause the averages of sea temperature employed were based on t periods of observation at the stations; and the number of at which observations had been made was so small that no tive means were available of ascertaining how far, and in what is, the sea temperatures used were themselves modified by land is.

Proceedings of the Royal Society of Edinburgh for 1862 contains a r Dr. J. Stark "On the Temperature of the Sea around the f Scotland during the years 1857 and 1858"; and the same observations, continued to 1864, is dealt with by Dr. A. in the *Journal of the Scottish Meteorological Society* for October Dr. Buchan draws some conclusions which are, in the main, d by the more adequate data now in existence; but his material d from nine stations only, and some of the records are irregular. iolas Whitley, in an essay on "Sea Temperature" published in *ial of the Royal Agricultural Society*, and another in the *Journal of Institution of Cornwall* "On the Temperature of the Sea and its ; on the Climate and Agriculture of the British Isles," both in scusses observations from a number of stations all round the

coast, which are described as "mean temperatures of the sea for the months, from many observations," the date being about 1851. These observations were used by Henry Hennessy, F.R.S., in his "Report on the Temperature of the Surface of the Sea on the Coasts of Great Britain and Ireland, and on the West Coast of France," included in the *Report of the Commission on the Methods of Oyster Culture*, issued in 1870. The Cornish observations have been continued and published from time to time in the *Reports of the Royal Cornwall Polytechnic Society*, along with occasional papers by Mr. W. P. Dymond (1875), Dr. C. Barham (1875 and 1879), and Mr. W. L. Fox (1879 and later). I am specially indebted to Mr. W. L. Fox for abstracts of the excellent series of observations from Falmouth, begun by Mr. W. P. Dymond in 1871.

The importance of sea temperature observations in investigations connected with fishery questions was strongly emphasised by the work of the Oyster Commission already referred to, and of the Herring Fishery Committee appointed by the Scottish Meteorological Society in 1873. In co-operation with the Fishery Board for Scotland, the Committee of the Scottish Society obtained a large number of temperature observations taken by fishermen on the herring-grounds on the East coast of Scotland; and these, combined with an excellent series taken at Peterhead (discussed separately—*Journal of the Scottish Meteorological Society*, March 1879), first made it possible to estimate the relation of observations made at coast stations to those made some distance from shore. The fishermen's observations were used to some extent in the Reports of the Herring Fishery Committee, but were first fully worked up by myself in 1889 (*Jour. Scot. Met. Soc.* vol. viii. p. 332).

As a result of representations, made in the first instance to the Board of Trade,[1] the Meteorological Committee of the Royal Society induced some of its reporters to begin observations of sea temperature in 1871 and 1872; and in 1873 the Lighthouse Boards agreed to co-operate by having observations made at a number of lighthouses and lightships. All these observations were at first unfortunately made at 12 o'clock noon.

In 1879 a system of observations at coast-guard stations was begun, the temperatures of sea and air being taken twice daily "at or about sunrise" and at 4 p.m. The observations on the light-vessels were brought into conformity with this system, which has been maintained ever since. The results of the sea temperature observations for three years from 1879 were shown in a series of maps in the "Meteorological Atlas of the British Isles" issued by the Meteorological Office in 1883, but necessarily without critical discussion. The records for the stations on the East coast of Scotland down to the end of 1886 were worked up and published in my paper already referred to, and it was the opinion I then formed of these observations that led me to undertake the present investigation, which is, for the most part, an extension of the same work so as to include the whole of the British coasts, and the period of 18 years from the beginning of 1880 to the end of 1897. Through the courtesy of the Meteorological Council I have been furnished with all the original documents, most of which reached me exactly as they were received by the Office, no attempt having been made to work them up.

[1] See R. H. Scott, *Quart. Jour. Met. Soc.*, 1875, p. 396.

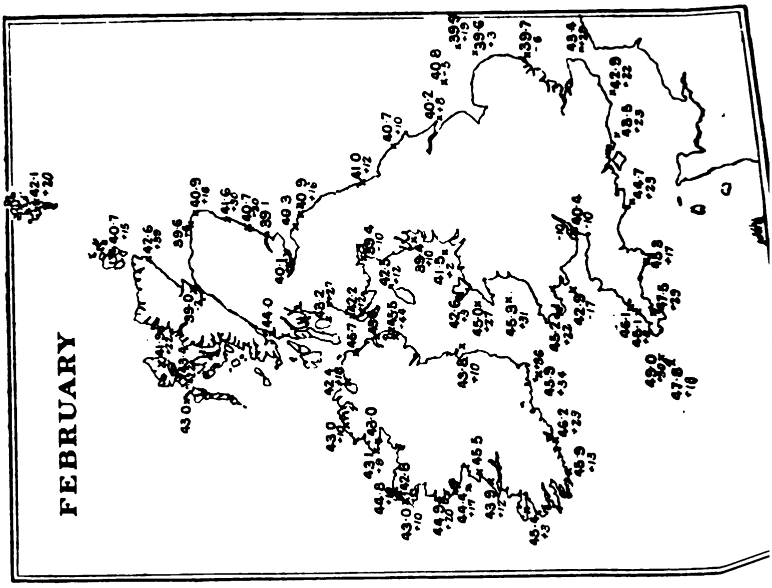
Examination and Averaging of the Coast-Guard Observations.

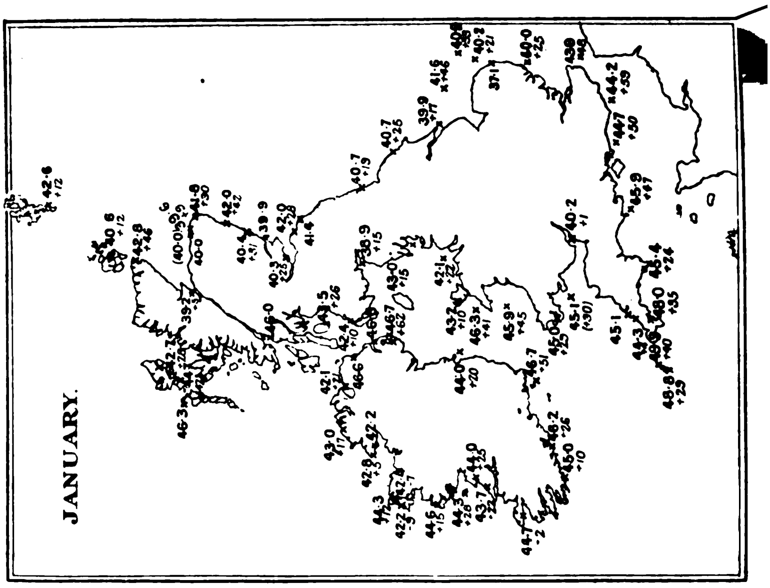
It should be stated at the outset that in most cases the observations, as such, are not of first-rate quality. Apart from defects due to local conditions, which may cause the temperature of the water at the place of observation to vary in such a way that it does not represent the general temperature in the neighbourhood, some of the observations are obviously made by careless or incompetent observers. The whole of the records for each station were carefully examined separately, and obvious errors of reading of 5° or 10° were corrected. When the observations were not fairly consistent after a legitimate application of these corrections they were rejected. Owing to frequent changes in observers, who are (in the case of the coast-guard stations) mostly "chief boatmen," the quality of the records tends to vary considerably—some stations being unfortunate in having a succession of bad observers, hence some months have occasionally to be rejected from an otherwise good station. Another cause of irregularity is due to the exigencies of the coast-guard service—the staff at the stations being often absent "watching wrecks," and so on. The observations at light-vessels are, for the most part, of better quality, and also the records are more continuous than is the case at the coast-guard stations; they are also, as a rule, free from defects incident to position—shallow water, etc.

After careful examination in the manner described, the observations were averaged for each month. It was found impossible, partly on account of the difficulty of obtaining and applying instrumental corrections, and partly because of the immense increase of labour which would have been involved, to reduce the averages to a true standard. However, the quality of the observations relatively to that of the instruments seemed to make this unnecessary in any case.[1]

The monthly averages for morning and evening were then combined, and the means for the various stations compared month by month with each other, in view of the geographical position and local conditions of each, so as to form an opinion on their value as representing mean temperatures at the different parts of the coast. The mean differences between the a.m. and p.m. observations, calculated for seven years where possible (usually 1891-1897), were extremely valuable in this respect. The differences in all the years were compared with them, although it was not thought worth while to make the actual calculation throughout. In the cases where means for the months were absent from the records from any of the causes described, the defect was made good by interpolation of values obtained by differentiation from another station which examination showed to have comparable geographical conditions; but in only one case were more than three consecutive months filled up in this way. The following notes with reference to the stations were made at this stage of the work, and may serve to show the impression given by examination of the records from each station, before the averages were compared on the maps.

[1] I have had assistance from time to time in parts of the computing work; and in part of both revising the observations and computing averages I had the assistance of Major Rooper King, to whom my best thanks are due.


FEBRUARY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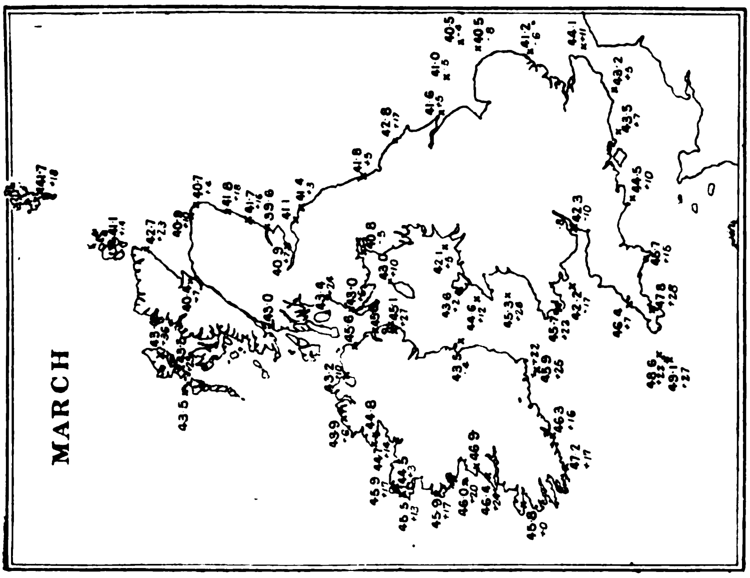


FIG. 3.

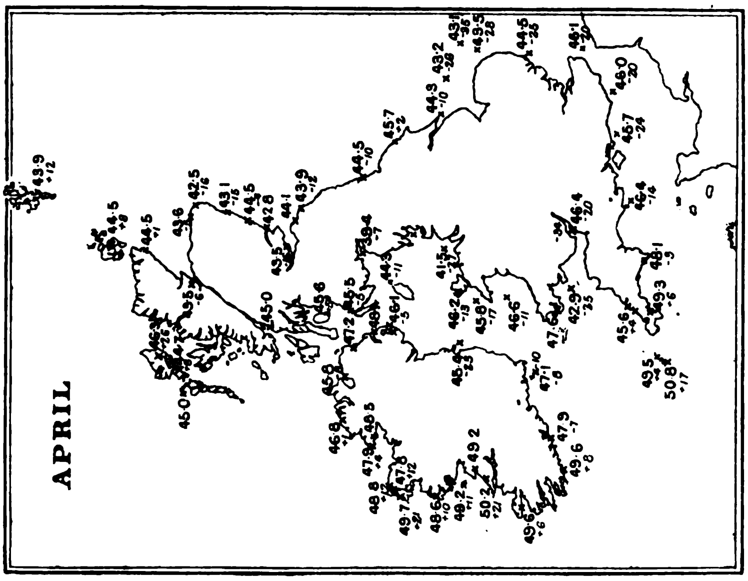


FIG. 4.

ENGLAND.

Sunderland, Coast-Guard. 17 years, 1880-96.—A continuous record, very fairly good throughout. Daily range very uniform.

Scarborough, C.G. 12 years, 1880-81, 1883-84, 1890-97.—This series is very irregular; bad in the earlier years,—1882, and 1885-89 had to be rejected bodily,—great improvement after 1893. The averages accepted agree well with Sunderland during the winter months, temperature higher and range greater in summer.

Spurn Head, Light-Vessel. Depth 9 fathoms. 13 years, 1880-84, 1890-97.—Years 1885-89 too broken to be of use, a fair record otherwise. Small range in winter and wide range in summer remarkable. Influence of Humber evidently strong.

Outer Dowsing, L.V. West of Shoal. Depth 10½ fathoms. 18 years, 1880-97.—Record complete and uniformly good throughout. One of the best stations.

Leman and Ower, L.V. Between Leman and Ower Sand. Depth 16 fathoms. 18 years, 1880-97.—Some months wanting in 1881; 1884, 1889, and 1892 have been interpolated. Observations very consistent, but both here and at Newarp variations are greater than at Outer Dowsing.

Newarp, L.V. Near North Cross Sand. Depth 17 fathoms. 15 years, 1880-85, 1887-88, 1890-97.—Averages and range agree fairly well with Leman and Ower, but the records are irregular—many gaps, partly due to breaks and partly due to bad observations. Years 1887 and 1889 had to be rejected; several interpolations in 1880, 1881, 1883, 1884, and 1890.

Shipwash, L.V. Off north-east end of Sand. Depth 9 fathoms. 15 years, 1880-86, 1888-90, 1893-97.—Rather broken. Good on the whole. Note similarity to E. Goodwin in summer, and wide difference from it in winter.

East Goodwin, L.V. 1½ mile from edge of Sand. Depth 30 fathoms. 18 years, 1880-97.—Continuous, except for break at end of 1884; last three months interpolated. Observations fairly satisfactory all through. Note agreement with stations in Channel rather than with those on East Coast.

Royal Sovereign, L.V. ¾ mile south of Southern Head, *i.e.* 1¾ mile south the Shoals. Depth 12 fathoms. 18 years, 1880-97.—Break of five months 1892, which it seemed possible to interpolate with confidence by reference Owers L.V. An exceptionally good station throughout.

Owers, L.V. About ½ mile south of the Outer Owers (rocks). Depth 16 fathoms. 17 years, 1881-97, practically complete.—Another very good record. Note high temperature in July and August here and at the Royal Sovereign compared to the rest of the Channel.

Shambles, L.V. Off the east end of the Shoal. Depth 15 fathoms. 17 years, 1881-97, practically complete.—Observations very good all through. Small annual range, probably due to strong tidal currents. Position evidently exceptionally good.

Salcombe, C.G. 17 years, 1880-86, 1888-97. The year 1887 too fragmentary to interpolate.—A good record, especially in the later years: the observations are evidently carefully taken in deep water.

Falmouth, 14 years, 1872-85.—These are mean temperatures extracted from the table given by Mr. W. L. Fox in the *Report of the Royal Cornwall Polytechnic Society* for 1886, p. 228. They may be accepted as thoroughly reliable.

Scilly, 11 years, 1887-97.—These observations are not taken daily, which may partly account for their unsatisfactory character. The means for several of the months refuse to compare with Seven Stones or any other station. Results to be regarded with suspicion all through.

Seven Stones, L.V. About $1\frac{1}{2}$ mile east-north-east of the rocks. Depth 40 fathoms. 13 years, 1881-85, 1889, 1891-97. Record broken in 1886-88 and 1890, but no values have been interpolated.—Observations very good.

Newquay, C.G., 7 years, 1891-97.—Observations regular and seem carefully taken, the monthly averages give good results, but the daily range is excessive. Must be used with caution.

Padstow, C.G., 8 years, 1880-87.—Good observations. Daily range much less than at Newquay—position probably better. Have combined the two stations with fairly successful result.

English and Welsh Grounds, L.V., between the English "ground" and the Welsh. Depth 8 fathoms. 18 years, 1880-97.—Record practically unbroken. This is a very careful series, and is of special interest from the varying effect of the river water at different seasons.

Helwick, L.V., at the west end of Helwick shoal. Depth $16\frac{1}{2}$ fathoms.—Only two years' records, for 1880 and 1881, were obtained from this station, but as the observations are good and the position is of interest an attempt has been made to reduce to a true mean by differentiation with Padstow and the English and Welsh Grounds, L.V. Result may be used with reserve.

St. Ann's Head, Pembroke. 10 years, 1872-77, 1894-97.—Single observations daily at noon in earlier years. No data to correct for daily range. A fairly good station.

Cardigan Bay, L.V. About 22 miles south-west of Bardsey Island Lighthouse. Depth 35 fathoms.—This station lies farthest from land of any, and a note on the chart on its position is important:—"Imperceptible indraught, but strong with west and south-west gales." The position is so favourable that the irregularity of the record is greatly to be regretted; only 12 years, 1881, 1882, 1884, 1889-97, could be computed. The observations seem good.

Carnarvon Bay, L.V. Between Bardsey Island and the South Stack. Depth 30 fathoms. 18 years, 1880-97.—An almost unbroken record; observations good. The means agree closely with Cardigan Bay.

Holyhead Old Pier.—The eleven years 1887-97 have been taken, the older observations dating back to 1871 seemed less satisfactory, the hour of observation is noon, and observations are not made every day.

N.W. Liverpool, L.V. The farthest out mark in Liverpool Bay—west of the 3 and 4 fathoms. Tongue. Depth 13 fathoms.—This light-ship is occasionally moved. 16 years, 1880, 1881, 1883-91, 1893-97. Observations only fair, unsatisfactory in the earlier years.

Bahama Bank, L.V., $1\frac{1}{4}$ mile south-east of Tail of the Bank. Depth 11 fathoms. 18 years, 1880-97. Three months wanting in the summer of 1886 and 1887, filled in by interpolation.—A very good record.

Solway, L.V., Robin Rigg Channel. Depth 5 fathoms. 13 years, 1885-97. Rather irregular, but results interesting from position. Compare with English and Welsh Grounds, L.V.

Scotland.

Ballantrae, C.G., 18 years, 1880-97.—Record very complete and the observations fair. The daily range seems rather too great.

Lamlash, C.G., 18 years, 1880-97.—Observations good, except during the first two years.

Stornoway, C.G., 13 years, 1883, 1891-97.—These observations are rather uncertain, but the range for the years 1891-97 works out satisfactorily. Mr. Scott has remarked that as Stornoway is situated on a tidal harbour, easy access to deep water is not attainable. The C.G. records have been combined with the older series belonging to the Scottish Meteorological Society covering the

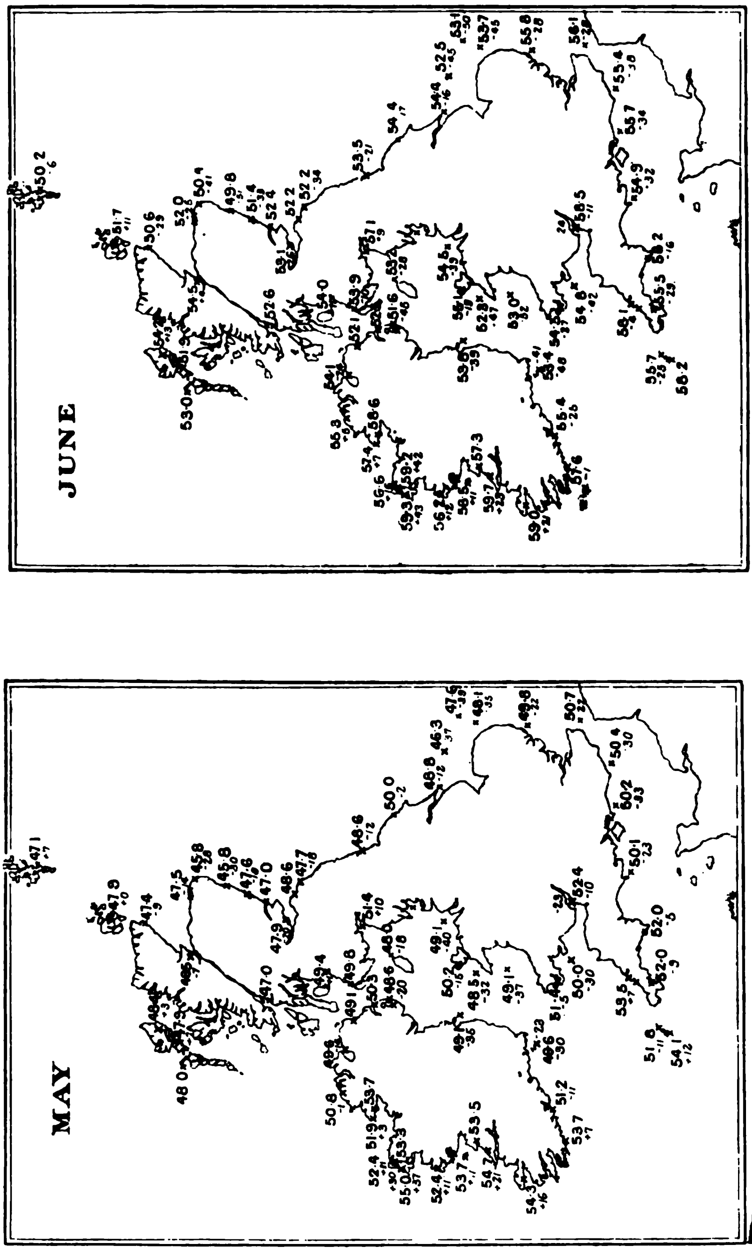


FIG. 6.

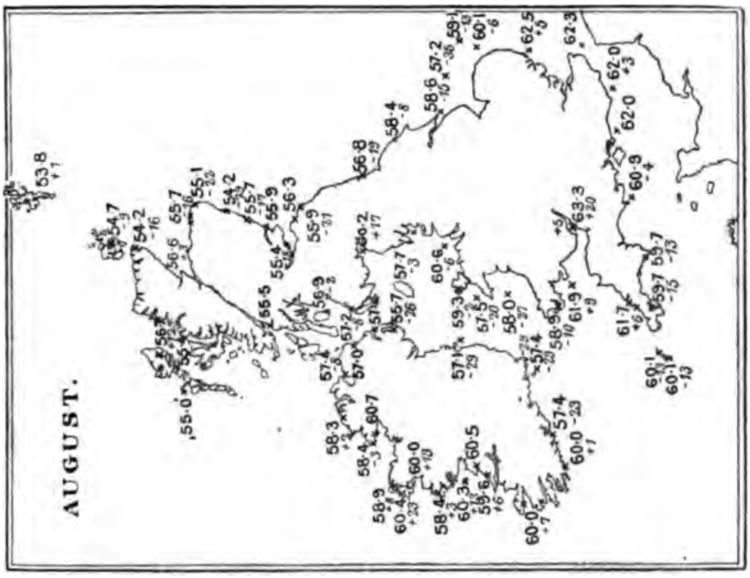


Fig. 8.

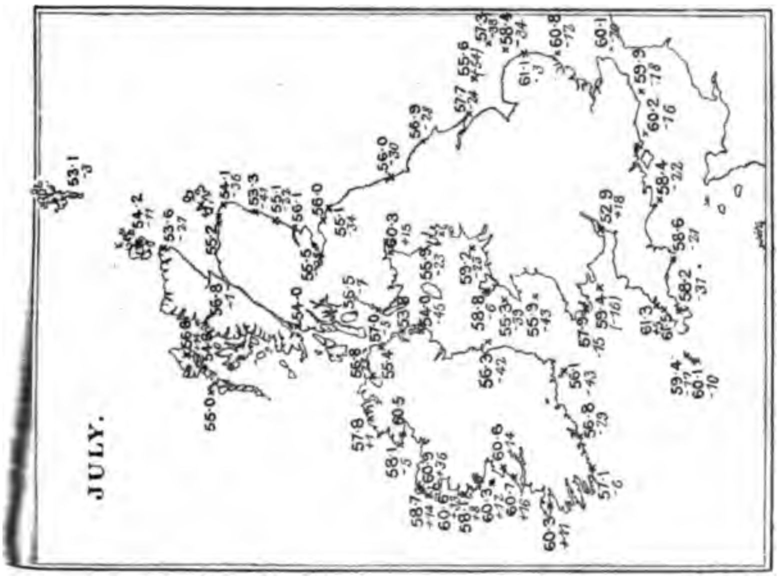


Fig. 7.

years 1859-80, and the mean given is therefore for 35 years. The earlier observations seem better than the C.G. series.

Lerwick, C.G., 18 years, 1880-97.—Record complete throughout.

Kirkwall, C.G., 17 years, 1880-86, 1888-97. Six months wanting in summer of 1887, and an occasional month here and there.—A good record. Position rather land-locked.

Wick, C.G., 11 years, 1880-83, 1887, 1892-97.—These observations are only fairly good; parts of the records have had to be rejected, and the daily range in summer is excessive. The means are, however, fairly reliable on the whole, and the station shows peculiarities which can scarcely be accounted for by defects in the observations; *e.g.* relatively high temperature in winter.

Cromarty, C.G., 17 years, 1881-97.—Record complete. The observations appear good throughout from internal evidence, but it is almost impossible to compare this station directly with any other.

Fraserburgh, C.G., 5 years, 1883-87.—This record is unsatisfactory, and the observations are only accepted because the averages compare fairly well with those for Pennant.

Pennant, C.G., 8 years, 1889-93, 1895-87: six months of 1894 wanting.—This is a very good record. It has been combined with the corrected Fraserburgh averages, giving a 13 years' series which is fairly satisfactory.

Aberdeen, Cove Bay, C.G., 18 years, 1880-97. The last three months of 1889 are interpolated, otherwise the record is complete.—One of the best stations.

Uzon, Montrose, C.G., 15 years, 1883-97.—A very good record, especially in the later years. The influence of the land seems more marked in winter than in summer.

Burntisland, C.G., 18 years, 1880-97.—Record complete and observations good. Curve might have been expected to show influence of the land more.

Burnmouth, C.G., 9 years, 1889-97.—Observations only fairly good: the daily range is rather high, but agrees well with Sunderland. In view of this the high winter temperatures are noteworthy.

IRELAND.

Kish Bank, L.V., 1¼ mile from the north end of the Bank; depth [illegible] fathoms. 14 years, 1881-83, 1885-90, 1892-97.—Record fairly continuous, but observations not very satisfactory. Daily range too great. Much shallow water in neighbourhood.

Coningbey, L.V., 2 miles south-west of Conningbeg Rock, the outermost of the Saltees. Depth 29 fathoms. 15 years, 1882, 1884-97.—Very good station.

Daunt's Rock, L.V., about 6 miles south-west from Roche's Point. Depth 16 fathoms. 15 years, 1880-82, 1885-96. A good record: last three months of 1896 wanting.—Note steady temperature in January, February, and March.

Castletownshend, C.G., 7 years, 1880-85, 1887.—Observations poor. Annual and daily ranges much too great.

Minard, C.G., 16 years, 1880-84, 1887-97.—Record continuous. Observations fairly good.

Seafield, C.G., 7 years, 1891-97.—Not good.

Liscannor, C.G., 7 years, 1880-84, 1896-97.—Observations bad. Only retained for comparison with Seafield and Aran.

Aran North, C.G., 9 years, 1889-97.—Observations regular and good. Position seems best in this region.

Cleggan, C.G., 17 years, 1881-97.—Daily range rather large, but observations are careful, and the averages work out well.

Blacksod Point, C.G., 7 years, 1891-97.—Good.

Claggan, C.G., 7 years, 1881, 1885-90.—Poor. Note that these two stations are more sheltered from the open sea than Ballyglass.

Ballyglass, C.G., 18 years, 1880-97.—Record unbroken. Observations fairly good, especially in later years. Note that all the stations between Minard and this have large daily range, except Aran.

Killybegs, C.G., 5 years, 1880-84.—Very indifferent.

Teelin, C.G., 9 years, 1889-97.—Observations very good.

Dunfanaghy, C.G., 18 years, 1880-97.—Record continuous. Observations excellent all through.

Portrush, C.G., 18 years, 1880-97. July to September 1894 interpolated.—This station not very satisfactory; the observations are rather inconsistent, and daily range very great in summer.

South Rock, L.V., 2 miles east of South Rock. Depth 30 fathoms. 18 years, 1880-97. April to June of 1880 interpolated.—Observations good throughout.

The observations from nine stations have been rejected bodily, as either hopelessly inaccurate, or made in very shallow water. The averages for the above stations will be found in Table I.

The mean temperatures for January, July, and the year were charted, and a further careful examination made, with the result that the means at five different stations seemed to require correction in the same sense in all three maps, viz.:—

Sunderland, a correction of	+0°·6
East Goodwin, ,, ...	−0 ·5
St. Ann's Head, ,, ...	−0 ·8
Claggan, ,, ...	+0 ·5
Fraserburgh, ,, ...	+0 ·5

(A correction of +0°·8 was made to the Fraserburgh averages in my previous paper, but as the +0°·5 was arrived at without reference to or recollection of the other, it is allowed to stand.)

These corrections have been applied in all the maps for each month (Figs. 1-12). The mean values of stations given in the different papers referred to were next examined, and inserted on the maps unless they appeared untrustworthy or of unduly short period, or were superseded by better data. The chief additions, which are given, along with the other values in Table I., are:—

England.—None.
Scotland.—Oban, Harris, Bernera, Peterhead, Abertay L.V., Dunbar.
Ireland.—Donaghadee, Cushendall.

An examination of the map for the year (Fig. 13, p. 290) confirms the opinion expressed in my previous paper, that the average of a comparatively small number of years gives a fair approximation to a true mean. No marked difference is noticeable between the stations having the full record of 17 or 18 years, and those having much shorter periods. Hence any attempt at differentiation is unnecessary: it would, as a matter of fact, be impossible to carry it out successfully.

Mean Daily Range of Temperature. (Table II.)

The material under discussion unfortunately affords no fresh information as to the hourly variation of temperature at the surface of

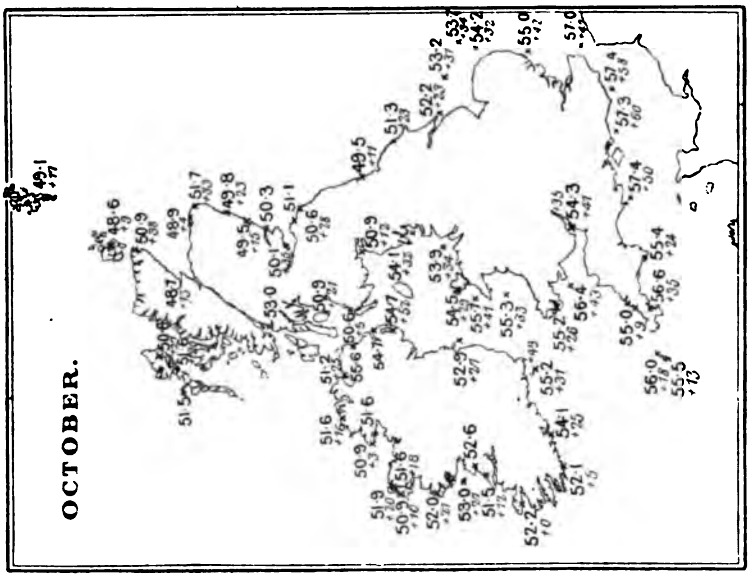


FIG. 10.

FIG. 9.

FIG. 12.

FIG. 11.

the sea. The data given by Dr. Buchan, based on observations taken at Harris between May and November 1863, are still the best available. It appears that the minimum temperature is reached about 6 a.m., and the maximum at 4 p.m., the changes of temperature occurring very slowly in the early morning hours: hence the value $\frac{1}{2}$ ("at or about sunrise" + 4 p.m.) must be a close approximation to a true mean for the day at all seasons of the year. In my previous work harmonic analysis of nine years' observations made at four-hour intervals during

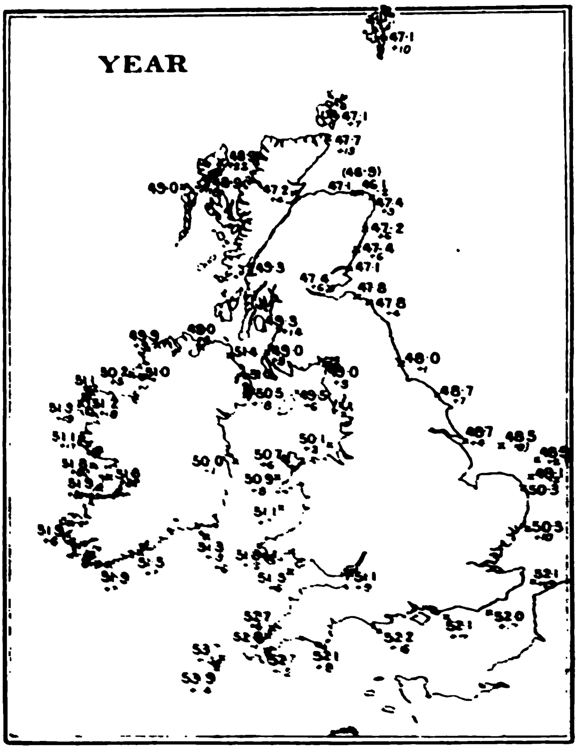


FIG. 18.

August on the Fishery cruiser *Vigilant* in Peterhead Bay, showed that the daily maximum occurred at 3 p.m. and minimum at 3 a.m., the corrections to reduce to mean for the day being:—

4 a.m.	8 a.m.	Noon.	4 p.m.	8 p.m.	Midnight.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	−0°·3

A number of single 24 hour sets of observations at Falmouth, lent to me by Mr. W. L. Fox, give similar curves. Hence it seems fair to conclude further that the difference of the two observations at the coast-guard stations and light-vessels gives a fair approximation to the real daily range. The differences have been accordingly referred to in the preceding notes as "daily ranges" and assuming that this is correct, they afford important addition to the means of valuing the different records.

TABLE I.—MEAN MONTHLY AND ANNUAL TEMPERATURE OF SURFACE WATER.

ɪTATION.	No. of Yrs.	Years Specified.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
NGLAND.			°	°	°	°	°	°	°	°	°	°	°	°	°
rland . .	17	1880-96	*40·1*	40·4	41·2	43·9	48·0	52·9	55·4	**56·2**	54·5	48·9	45·2	41·3	47·4 [1]
rough . .	12	1880, 81, 83, 84, 90-97	*40·7*	*40·7*	42·8	45·7	50·0	54·4	56·9	**58·4**	56·1	51·3	45·8	42·0	48·7
. . . .	13	1880-84, 90-97	*39·9*	40·2	41·6	44·3	48·8	54·4	57·7	**58·6**	57·1	52·2	47·1	42·8	48·7
Dowsing .	18	1880-97	41·6	*40·8*	41·0	43·2	46·3	52·5	55·6	**57·2**	56·7	53·2	48·8	45·1	48·5
ı-and Ower .	18	1880-97	40·9	*39·9*	40·5	43·1	47·6	53·1	57·3	**59·1**	57·9	53·7	48·9	44·3	48·9
'p . .	15	1880-85, 87, 88, 90-95, 97	40·2	*39·6*	40·5	43·5	48·1	53·7	58·4	**60·1**	58·9	54·2	48·7	43·5	49·1
ash . .	15	1880-86, 88-90, 93-97	40·0	*39·7*	41·2	44·5	49·8	55·8	60·8	**62·5**	60·8	55·0	49·2	43·9	50·3
odwin . .	18	1880-97	44·4	*43·9*	44·1	46·6	51·2	56·5	60·6	**62·8**	62·2	57·5	53·4	48·7	52·6 [2]
Sovereign .	18	1880-97	44·2	*42·9*	43·2	46·0	50·4	55·4	59·9	**62·0**	61·4	57·4	52·8	48·2	52·0
. . . .	17	1881-97	44·7	*43·5*	*43·5*	45·7	50·2	55·7	60·2	**62·0**	61·2	57·3	52·8	48·2	52·1
ɔles . .	17	1881-97	45·9	*44·7*	*44·5*	46·4	50·1	54·9	58·4	**60·9**	60·7	57·4	53·2	49·2	52·2
nbe . .	17	1880-86, 88-97	45·4	*45·3*	45·7	48·1	52·0	56·2	58·6	**59·7**	59·1	55·4	51·9	48·0	52·1
ıuth . .	14	1872-85	48·0	*47·5*	47·8	49·3	52·0	55·5	58·0	**59·7**	59·0	56·6	53·0	49·7	53·0
. . . .	11	1887-97	48·8	*47·8*	49·1	50·8	54·1	58·2	**60·1**	**60·1**	58·9	55·5	52·7	50·5	53·9
Stones .	13	1881-85, 89, 91-97	49·9	49·0	*48·6*	49·5	51·8	55·7	59·4	**60·1**	58·8	56·0	54·1	51·9	53·7
uay . .	7	1891-97	*44·3*	45·1	46·6	49·7	53·9	58·3	61·5	**61·6**	59·5	55·1	50·9	47·8	52·8
ɔw . .	8	1880-87	*45·1*	46·1	46·2	48·7	53·1	58·0	61·3	**61·9**	59·8	54·8	50·7	47·3	52·7
uay and Pad-	15	1880-87, 91-97	*44·7*	45·6	46·4	49·2	53·5	58·1	61·4	**61·7**	59·6	55·0	50·8	47·5	52·7
ɪh and Welsh ınds	18	1880-97	*40·2*	40·4	42·3	46·4	52·4	58·5	62·9	**63·3**	60·6	54·3	48·0	43·6	51·1
ck . . {	2	1880-81	42·6	42·0	43·7	46·1	50·6	54·6	59·6	61·8	60·5	55·6	51·2	48·0	51·4
	...	Mean	45·1	42·9	*42·2*	46·0	50·0	54·8	59·4	**61·9**	60·7	56·4	52·0	46·9	51·5
Ann's Head, broke	10	1872-77, 94-97	46·8	*46·0*	46·5	48·4	51·4	55·3	58·7	**59·7**	58·8	56·0	53·0	50·3	52·6 [3]
ȝan Bay .	12	1881, 82, 84, 89-97	45·9	*45·3*	*45·3*	46·6	49·1	53·0	55·9	**58·0**	57·8	55·3	52·3	48·9	51·1
rvon Bay .	18	1880-97	46·3	45·0	*44·6*	45·8	48·5	52·3	55·5	57·5	**58·1**	55·7	52·4	48·8	50·9
ıead Old Pier.	11	1887-97	43·2	*42·6*	43·6	46·2	50·2	55·1	58·8	**59·3**	58·3	54·5	50·6	45·9	50·7
L. V., Liver- B.	16	1880-81, 83-91, 93-97	42·1	*41·5*	42·1	45·1	49·1	54·5	59·2	**60·6**	59·3	53·9	49·2	45·1	50·1
ıa Bank .	18	1880-97	43·0	*42·5*	43·0	44·3	48·0	53·2	55·9	**57·7**	57·4	54·1	49·7	45·7	49·5
y . .	13	1885-97	*38·9*	39·4	40·8	45·2	51·4	57·1	**60·3**	60·2	57·0	50·9	45·7	41·6	49·0
OTLAND.															
trae . .	18	1880-97	42·4	*42·2*	43·0	45·5	49·8	53·9	57·0	**57·2**	55·8	50·6	47·2	44·1	49·0
sh, Arran .	18	1880-97	43·5	*43·2*	43·4	45·6	49·4	54·0	56·5	**56·9**	55·2	50·9	48·1	45·3	49·3
. . . .	?	?	46·0	44·0	*43·0*	45·0	47·0	52·6	54·0	**55·0**	**55·0**	53·0	50·0	47·0	49·3
'a . .	?	?	46·3	*43·0*	43·5	45·0	48·0	53·0	**55·0**	**55·0**	54·0	51·5	48·0	46·0	49·0
. . . .	5	1858-63	44·7	*43·4*	*43·5*	44·7	47·9	51·9	54·8	**55·4**	54·1	51·6	48·3	46·4	48·9
and Bernera	?	?	45·5	43·2	43·5	44·8	48·0	52·4	54·9	55·2	54·0	51·5	48·2	46·2	49·0
ıway . .	13	1883-88, 91-97	40·8	41·9	42·3	46·3	51·0	56·2	58·3	57·7	55·1	49·1	45·0	41·8	48·8
ıway . .	35	1859-80, 83-88, 91-97	42·7	*41·9*	43·4	46·3	48·4	54·2	**56·8**	**56·7**	54·9	50·6	46·9	44·2	48·9
:k . .	18	1880-97	42·6	42·1	*41·7*	43·9	47·1	50·2	53·1	**53·8**	52·3	49·1	46·0	43·6	47·1
all . .	17	1880-86, 88-97	*40·6*	*40·7*	41·1	44·5	47·9	51·7	54·2	**54·7**	53·1	48·6	45·2	42·3	47·1
. . . .	11	1880-83, 87, 92-97	42·8	*42·6*	42·7	44·5	47·4	50·6	53·6	**54·2**	53·1	50·9	47·8	44·9	47·7
rty . .	17	1881-97	39·2	*39·0*	40·4	43·5	48·5	54·5	**56·8**	56·6	53·0	48·7	44·6	41·0	47·2
burgh . .	5	1883-87	*39·6*	39·8	40·0	42·3	45·6	50·5	**54·8**	**54·8**	52·9	48·2	44·1	40·6	46·1 [4]
ɪt . .	8	1889-93, 95-97	40·0	*39·2*	41·1	44·1	48·3	52·7	55·2	**55·9**	53·8	49·1	44·4	41·3	47·1

Corrections to be applied :—[1] +0°·6. [2] −0°·5. [3] −0°·8. [4] +0°·5.

TABLE I.—Mean Monthly and Annual Temperature of Surface Water—*Continued.*

Station.	No. of Yrs.	Years Specified.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
Fraserburgh and Pennant (Corr.)	13	1883-87, 89-93,95-97	40·0°	39·6°	40·9°	43·6°	47·5°	52·0°	55·2°	**55·7°**	53·7°	48·9°	44·5°	41·2°	46·9°
Peterhead	7	1873-79	41·8	40·9	40·7	42·5	45·8	50·4	54·1	**55·1**	54·2	51·7	47·3	43·7	47·4
Aberdeen, Cove B.	18	1880-97	42·0	41·6	41·8	43·1	45·8	49·8	53·3	**54·2**	52·9	49·8	47·2	44·5	47·2
Uzon, Montrose	15	1883-97	40·4	40·7	41·7	44·5	47·6	51·4	55·1	**55·7**	53·7	49·5	45·7	42·3	47·4
Abertay L.V.	7	1880-86	39·9	39·1	39·6	42·8	47·0	52·4	**56·1**	55·9	54·3	50·3	46·1	41·9	47·1
Burntisland	18	1880-97	40·3	40·1	40·9	43·5	47·9	53·1	**55·5**	**55·4**	54·5	50·1	45·8	42·2	47·4
Dunbar	9	1857-65	41·4	40·3	[illegible]	44·1	48·6	52·2	55·7	**56·3**	55·2	51·1	46·6	43·9	48·0
Burnmouth	9	1889-97	41·4	40·9	41·4	43·9	47·7	52·2	55·1	**55·9**	54·4	50·6	47·3	43·3	47·8
Ireland.															
Kish Bank	14	1881-82, 85-90,92-97	44·0	43·8	43·5	45·4	49·1	53·8	56·3	**57·1**	56·2	52·9	50·2	47·2	50·0
Coningbeg	15	1882, 84-97	46·7	45·9	45·9	47·1	49·6	53·4	56·1	**57·4**	**57·5**	55·2	52·3	48·9	51·3
Daunt's Rock	15	1880-82, 85-96	46·2	46·2	46·3	47·9	51·2	55·4	56·8	**57·4**	**57·3**	54·1	50·9	48·5	51·5
Castletownshend	7	1880-85, 87	45·0	45·9	47·2	49·6	53·7	57·6	59·1	**60·0**	57·3	52·1	49·0	46·4	51·9
Minard, Dingle Bay	16	1880-84, 87-97	44·7	45·4	45·8	49·6	54·3	59·0	**60·3**	60·0	57·7	52·2	48·1	45·8	51·9
Seafield	7	1891-97	43·7	43·9	46·4	50·2	54·7	59·7	**60·7**	59·6	57·4	51·5	47·9	46·0	51·9
Liscannor	7	1880-4,96-7	44·0	45·5	46·9	49·2	53·5	57·3	**60·6**	**60·5**	57·9	52·6	48·7	45·4	51·8
Aran, N. Island	9	1889-97	44·3	44·4	46·0	49·2	53·7	58·5	**60·3**	**60·3**	58·6	53·0	49·0	45·8	51·8
Cleggan	17	1881-97	44·6	44·9	45·9	48·6	52·4	56·2	58·1	**58·4**	56·8	52·0	48·8	46·0	51·1
Blacksod Point	7	1891-97	42·2	43·9	45·5	49·7	55·0	59·3	**60·6**	60·0	57·3	50·9	47·1	44·4	51·3
Claggan	7	1881, 85-90	41·9	42·3	44·0	48·3	53·8	58·7	**60·4**	59·9	57·1	51·1	47·8	43·4	50·7[1]
Ballyglass	18	1880-97	44·3	44·8	45·0	48·8	52·4	56·6	58·7	**58·9**	57·0	51·9	48·5	45·7	51·1
Killybegs	5	1880-84	42·2	43·0	44·8	48·5	53·7	58·6	60·5	**60·7**	58·4	51·6	46·4	43·3	51·0
Teelin	9	1889-97	42·8	43·1	44·7	47·9	51·9	57·4	58·1	**58·4**	56·5	50·7	47·0	44·0	50·2
Dunfanaghy	18	1880-97	43·0	43·0	43·9	46·8	50·8	55·3	57·8	**58·3**	56·0	51·6	48·1	44·7	49·9
Portrush	18	1880-97	42·1	42·4	43·2	45·8	49·6	54·1	56·8	**57·4**	55·7	51·2	46·7	43·7	49·0
Cushendall	?	?	46·6	45·7	45·6	47·2	49·1	52·1	55·4	57·0	**58·3**	55·6	51·6	49·4	51·4
Donaghadee	?	?	46·5	45·6	45·6	48·1	50·3	52·5	55·8	57·4	**57·5**	54·7	50·1	49·3	51·0
South Rock	18	1880-97	46·7	45·5	45·1	46·1	48·6	51·6	54·0	55·7	**56·2**	54·7	52·4	49·5	50·5

Corrections to be applied :—[1] +0°·5.

The extent of the daily range appears to depend on strictly local conditions, and it is possible to have comparatively small annual range with a diurnal range above the average, and conversely. Thus at Seafield and Liscannor, in Co. Clare, the mean daily range is excessive, amounting to 2°·0 on the year, and about 3°·0 in early summer: Aran North Isle has a mean range less than half this amount, but the means are in fair agreement in all the months. Again, the English and Welsh grounds L.V., which shows a wide annual range on account of river water in the channel, has a remarkably small diurnal range—no more than that of light-ships moored in deep water well away from land. Claggan and Blacksod show, if anything, slightly smaller diurnal ranges than Ballyglass, but their annual ranges are greater; here there is probably little shallow water about, but Ballyglass is perhaps in a more exposed situation. The daily range at coast stations is thus evidently determined by the relation of the speed and duration of the tidal streams to the extent of shallow water, and of surface exposed between tide limits in the neighbourhood.

The eighteen stations marked *a* in the last column of Table II. (p. 294) have been selected as representative of the west coast of the British Isles directly open to the Atlantic; they give a mean daily range for the year 0°·7, with no distinct indication of progressive change as we go north or south, except in the case of Lerwick, which has a small range. Three stations marked *b* are taken to represent the North Sea coast of Great Britain, and give a daily range of 0°·8. The stations at Uzon, Cove Bay, and Pennant (marked *c*), which are known to be in or near a region of up-welling water, show a remarkably small range throughout the year. The mean for four stations in the Irish Sea (marked *d*), which could not be regarded as open to the Atlantic, is 0°·8, and for the 34 stations combined 0°·73, slightly less than that in the Atlantic in 30° N. and 42° W. 0°·8.[1] From general considerations it may be judged that the average daily range in the open sea is about 0°·5 south of the British Isles, and 0°·2 to 0°·3 in the region off the Orkneys and Shetlands.

With regard to the seasonal changes in the daily range the chief feature is the flatness of the curve both in winter and summer; and the rapid change in spring and autumn; on both east and west coasts the range remains steady at about 1°·0 from April to the beginning of September, and at about 0°·3 from November to February. This point may be worth further investigation in relation to the air temperatures, which vary in a somewhat similar manner but very irregularly, tending to maxima about the equinoxes.

The Distribution of Temperature.

The broader features of the distribution of temperature are perfectly simple. The average for the year at the entrance to the English Channel is nearly 54°, it falls, as the Channel narrows, to 52° between the Start and Cape la Hague, and remains steady to beyond the Straits of Dover, at least as far as the East Goodwin L.V.

On the south-west coast of Ireland the annual mean is about 52°, falling to 51° in St. George's Channel, and 50° in the Irish Sea. A slow fall from 52° to 50° takes place on the west coast of Ireland until the north-west corner is reached. The mean of 49° persists along the north coast of Ireland to the North Channel and along the whole of the west coast of Scotland to Stornoway.

On the east coast, temperature falls quickly, as soon as we get out of range of the Straits of Dover, to 50° off Suffolk and Norfolk, and then there is a gradual fall as we go northward, to 48° off the coast of Northumberland, 47°·5 off Aberdeenshire, and 47° at the Orkneys and Shetlands.

The effect of the tidal streams in mixing the waters is exceedingly well marked. The uniform temperature along the narrow part of the English Channel may be ascribed to their action, and they appear again in the North Channel (South Rock, Cushendall, and Donaghadee), and in the Pentland Firth (Wick). On the east coast of Great Britain and west coast of Ireland, where the streams are weaker, the normal fall of temperature towards the north becomes apparent. The great

[1] Buchan, *Ency. Brit.*, XVI. 7.

complexity of the tidal streams in the angle east of a line joining Malin Head and Cape Wrath, due to the extremely broken coast-line, is probably responsible for the uniform temperature within that area.

TABLE II.—MEAN DIFFERENCE OF TEMPERATURE OF THE SURFACE WATER "AT OR ABOUT SUNRISE," AND AT 4 P.M., TAKEN TO REPRESENT THE DAILY RANGE.

STATION.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.	
ENGLAND.	°	°	°	°	°	°	°	°	°	°	°	°	°	
Sunderland .	0·9	0·9	1·3	0·7	0·8	0·9	0·9	1·1	0·8	1·2	0·8	0·7	0·9	
Scarborough .	0·6	0·9	1·4	1·5	0·9	1·4	0·8	0·6	0·9	0·8	1·0	0·6	1·0	
Spurn Head .	0·1	0·3	0·9	1·6	1·6	1·5	1·1	1·6	1·2	0·7	0·2	0·1	0·9	
Outer Dowsing .	0·2	0·2	0·7	0·4	0·5	0·9	0·6	0·4	0·6	0·4	0·2	0·2	0·4	*b*
Leman and Ower	0·3	0·2	0·4	1·2	1·2	1·2	1·1	1·1	0·7	0·2	0·1	0·3	0·7	*b*
Newarp . .	0·5	0·5	0·8	1·0	0·9	1·4	1·3	1·1	0·9	0·5	0·7	0·2	0·8	*b*
Shipwash . .	0·3	0·3	0·6	1·1	1·1	0·8	1·0	1·0	0·5	0·6	0·6	0·3	0·7	
E. Goodwin .	0·1	0·3	0·3	0·6	0·8	1·0	1·1	1·4	0·7	0·2	0·1	0·4	0·6	
Royal Sovereign.	0·1	0·4	0·6	0·6	1·1	0·9	0·9	0·8	1·1	0·6	0·2	0·3	0·6	
Owers . .	0·2	0·4	0·5	0·7	0·6	1·0	0·9	0·5	0·9	0·5	0·2	0·1	0·5	
Shambles . .	0·2	0·3	0·3	0·6	0·7	0·9	0·9	0·7	0·5	0·4	0·3	0·2	0·5	
Salcombe . .	0·5	0·9	0·5	0·5	0·6	0·2	0·4	0·3	0·2	0·3	0·2	0·1	0·4	*a*
Seven Stones .	0·1	0·1	0·4	0·4	0·8	0·9	0·8	0·7	0·7	0·2	0·3	0·1	0·5	*a*
Newquay . .	0·6	0·8	1·4	1·9	2·2	2·5	2·2	2·2	1·8	0·7	1·0	0·8	1·5	*a*
English & Welsh Grounds	0·0	0·4	0·8	1·2	0·9	0·6	0·8	0·9	0·4	0·3	−0·2	0·0	0·5	
Cardigan Bay .	0·3	0·7	0·7	1·1	0·9	1·1	1·2	0·9	0·5	0·6	0·3	0·2	0·7	*a*
Carnarvon Bay .	0·5	0·3	0·5	0·8	1·1	1·3	1·3	0·9	0·6	0·4	0·0	0·0	0·6	*a*
N.W.L.V., Liverpool Bay	0·4	0·5	0·8	1·3	1·6	1·5	1·7	1·1	0·8	0·3	0·5	0·1	0·9	*d*
Bahama Bank .	0·4	0·5	1·0	1·2	1·3	1·6	1·5	1·1	0·9	0·2	0·1	0·2	0·8	*d*
Solway . .	0·7	0·7	1·3	1·9	2·1	2·6	2·2	1·4	2·0	1·6	1·0	c·6	1·5	
SCOTLAND.														
Ballantrae . .	0·5	0·8	1·0	1·5	1·8	1·9	1·7	1·3	1·1	0·9	0·6	0·2	1·1	
Lamlash . .	0·4	0·5	1·2	1·3	1·9	1·1	1·4	1·3	1·7	1·1	0·5	0·8	1·1	*a*
Stornoway .	0·5	0·7	0·6	1·3	1·2	0·9	1·6	1·0	0·4	0·5	0·5	0·3	0·8	*a*
Lerwick . .	0·2	0·2	0·3	0·3	0·3	0·3	0·4	0·2	0·3	0·0	0·2	0·1	0·2	*a*
Kirkwall . .	0·1	0·4	0·5	0·4	0·6	0·6	0·6	0·6	0·6	0·4	0·8	0·5	0·5	*a*
Wick . .	0·3	0·3	0·3	0·5	1·6	1·9	1·7	1·4	1·6	1·6	0·7	0·3	1·0	
Cromarty . .	0·2	0·4	1·2	1·5	1·4	1·7	1·8	1·6	1·1	0·9	0·8	0·4	1·1	
Pennant . .	0·1	0·0	0·2	0·3	0·4	0·1	0·4	0·3	0·3	0·1	0·0	0·0	0·2	*c*
Aberdeen, Cove Bay	0·3	0·2	0·4	0·4	0·7	0·6	0·3	0·5	0·4	0·4	0·3	0·2	0·4	*c*
Uzon, Montrose	0·2	0·2	0·0	0·0	0·1	0·4	0·4	0·5	0·4	0·2	0·2	0·2	0·2	*c*
Burntisland .	0·3	0·2	0·6	0·7	1·2	0·8	1·0	1·1	0·8	0·5	0·2	0·2	0·6	
Burnmouth .	0·4	0·5	0·8	1·6	1·4	1·4	1·2	1·4	1·0	0·6	0·4	0·3	0·9	
IRELAND.														
Kish Bank .	0·9	0·4	1·0	1·4	1·9	1·5	1·6	1·1	1·2	0·6	−0·6	0·1	0·9	*d*
Coningbeg .	0·3	0·4	0·4	0·7	1·1	0·9	1·0	0·9	0·8	0·4	0·2	0·1	0·6	*a*
Daunt's Rock .	0·4	0·3	0·9	1·0	1·2	1·0	1·2	0·9	1·2	0·8	0·2	0·1	0·8	*a*
Minard, Dingle Bay	0·5	0·9	1·4	1·7	2·0	1·6	1·5	1·4	1·4	0·9	0·4	0·3	1·2	*a*
Seafield . .	1·1	1·9	1·8	2·8	2·9	2·3	2·6	2·4	2·3	1·8	1·0	0·8	2·0	*a*
Cleggan . .	0·6	0·9	1·5	2·1	2·2	1·6	2·0	1·6	1·3	1·0	0·4	0·6	1·3	*a*
Blacksod Point .	0·7	0·7	1·0	1·6	1·6	1·9	1·8	1·5	1·2	1·1	0·6	0·5	1·2	*a*
Ballyglass . .	0·6	0·9	1·7	2·4	2·1	1·7	1·6	1·8	1·6	1·1	0·9	0·6	1·4	*a*
Teelin . .	0·2	0·5	0·8	1·1	1·2	1·0	1·1	0·8	0·5	0·7	0·6	0·3	0·7	*a*
Dunfanaghy .	0·4	0·8	0·8	1·4	1·1	1·2	1·1	0·9	0·8	0·5	0·4	0·2	0·8	*a*
Portrush . .	0·9	1·0	1·6	1·8	2·8	3·2	2·4	2·3	2·9	2·3	1·3	1·1	2·0	
South Rock .	0·1	0·2	0·8	0·8	1·4	1·5	1·2	0·8	0·6	0·3	0·2	0·1	0·7	*d*

After making allowance for the modifications produced by the tidal action, the effect of north-easterly drift motion of the surface water can

be more clearly distinguished. It becomes more and more marked as we go northward. Thus the mean annual surface temperature is the same off the south and west of Ireland, as off the coasts of Sussex and Kent, the tides keeping up the temperature at the east end of the Channel by mixing with the warmer water from the mouth. Harris and Stornoway have the same temperature as the region near the Wash, 5° further south, and Kirkwall and Lerwick the same as the coasts of Forfarshire and Aberdeenshire. The temperature falls at the rate of about 0°·6 for each degree of increase of latitude all along the western coasts from 50° N. to 60° N. Table III. shows that away from the land, in 15° W. long., the rate of fall is almost exactly the same, but the temperatures are about 3° higher; the mean position of the thermal axis of the north-east drift is therefore well out in the Atlantic. This may be made clearer thus :—

	West coast of British Isles.	Meridian of 15° W.	Diff.
Lat. 60°	47°	50°	3°
	Diff. 3°	Diff. 3°	
55°	50°	53°	3°
	Diff. 3°	Diff. 3°	
50°	53°	56°	3°

The general north and south distribution of temperature remains unaffected eastwards even when the coasts are reached, and lateral branches are thrown out according to the configuration of the land, modified, and in some cases reinforced, by the action of the tides.

TABLE III.—Mean Temperature of Air and Sea Surface in Latitudes 50° N., 55° N., and 60° N., in Longitude 15° W. The sea temperatures for the months are taken from the Charts published by the Meteorological Office; the air temperatures are calculated from the American *International Bulletin* for the years 1881 to 1886. The data in the last column, from the Charts published in the *Challenger Reports*, are given for comparison.

		Feb.	May.	Aug.	Nov.	Mean.	Year.
		°	°	°	°	°	°
Lat. 50° N.	Sea	52·0	54·5	61·5	55·1	55·8	56·3
	Air	49·5	55·2	62·6	53·0	55·1	55·0
	Difference	+2·5	−0·7	−1·1	+2·1	+0·7	+1·3
Lat. 55° N.	Sea	50·0	52·0	57·5	52·0	52·9	52·9
	Air	44·3	51·1	57·8	47·4	50·1	49·7
	Difference	+5·7	+0·9	−0·3	+4·6	+2·8	+3·2
Lat. 60° N.	Sea	46·5	50·0	55·1	48·0	49·9	50·5
	Air	38·0	45·3	53·5	41·0	44·4	45·0
	Difference	+8·5	+4·7	+1·6	+7·0	+5·5	+5·5

In examining the changes of temperature from month to month, the outstanding feature is of course the flatness of the curves at stations open to the ocean. The data in Table I., however, make it necessary to modify some statements which are constantly brought forward to account for climatic phenomena observed in different parts of these islands. The annual minimum of surface temperature rarely occurs in March, and if it does the mean temperature is scarcely different from that of

February. The average of eight stations in the south-west of England shows a minimum occurring in February, with a fall of 0°·6 from January and a rise of 0°·3 to March. Thirteen stations on the west and south-west of Ireland have their minimum in January, with a difference of + 0°·4 between January and February and of + 1°·2 between February and March. Nearly all the stations on the North Sea coasts have their minimum in February, usually with a marked rise to March, and the minimum falls between February and March at the eastern end of the English Channel (including the East Goodwin), off the west coast of Wales, and in the North Channel. The annual maximum occurs almost everywhere in August, with a tendency, not well marked, to fall earlier and later at the same places as the minimum; indicating, or at least hinting; since we know that the movements of the drift currents are widely different in summer and winter; that the periodic changes are to a large extent due to local causes, superposed on the external causes which give the water its actual temperature, a result which Table II. rather leads us to expect.

The conditions governing the distribution of surface temperature in the different seasons are therefore to be ascertained from a comparison of the monthly averages on the east and west coasts—*i.e.* in the open and confined areas. This may be done either from the records of individual stations, selected with due regard to the merits of each as described in the notes given above, or by comparing averages obtained by inspection from the charts, the merits of the stations being again borne in mind. Table IV. (p. 297) contains the results of a series of such comparisons, and explains itself. Columns 1, 2, and 7 concur in showing that the difference in temperature between the east and west is immensely greater in the first half of the year than in the second; the winter conditions, of great difference, do not probably obtain till November, and they continue till May. Columns 3, 4, and 5, although no doubt slightly modified by the local peculiarities of the east coast stations, show that the differences not only decrease toward the north, but tend more towards distinct maxima and minima in the middle of winter and summer. Column 8 shows that the relatively higher temperature seawards is entirely confined to the winter months, as appears at once from the shape of the isothermals, and that the effects of land-heating in summer on the west coast are slight. Column 6 shows a remarkable modification of the normal conditions in the east of the English Channel, probably due to the great amount of sunshine in summer heating the water to a greater extent than on the east coast, and reversing the effect which should be produced by the tidal mixing (see Table V., p. 299). Thus the contrary action of the tidal mixing and the increasing land influence tend to keep the temperature uniform at all seasons, the former smoothing up and delaying the minimum and the latter neutralising the depressing effect on the maximum.

Columns 9, 10, and 11 show the differences between north and south stations on the eastern and western coasts; the differences in 9 and 10 remain fairly constant throughout the year, compare this with the temperature gradient in long. 15° W. (cols. 12, 13, and 14). Column 11 is of course a similar curve to Column 1.

A complete explanation of the facts set forth in Tables III. and IV.

would be considerably beyond the scope of the present paper. It appears, however, that the north to south temperature gradient in *e.g.* long. 15° W. is steepest during the latter half of the year, on account of the high summer and autumn surface temperature in the lower latitudes, and that this tends to equalise itself between latitudes 50° and 60° early in the spring, the temperature becoming relatively higher towards the northward, producing an early minimum on the west coast. The isothermal surface slopes northward, as it were, at the end of summer; the slope gradually turns to north-east and east during autumn and winter, returning to a northerly slope by the tilting-up of the southern

TABLE IV.—COMPARISON OF MEAN TEMPERATURE OF SURFACE WATERS AT CERTAIN PAIRS OF STATIONS.

Months.	1		2		3		4		5		6	
	°	°	°	°	°	°	°	°	°	°	°	°
January	4·6		8·3		5·5		3·5		5·1		2·6	
February	5·4	5·1	8·2	8·0	3·6	3·9	1·6	2·3	2·5	3·1	2·1	2·3
March	5·3		7·6		2·6		1·7		1·8		2·2	
April	4·7		6·3		1·2		1·7		0·3		2·8	
May	4·9	4·2	5·5	5·0	0·5	0·7	2·2	2·1	0·4	−0·1	4·1	3·3
June	2·9		3·2		0·4		2·5		−1·0		2·9	
July	1·2		3·8		−0·3		1·6		−0·2		3·3	
August	0·2	0·7	2·9	2·9	−0·5	−0·2	1·0	1·2	−0·5	−0·3	4·8	4·3
September	0·6		2·1		−0·3		1·1		−0·3		4·7	
October	0·9		3·8		2·6		1·7		2·0		3·9	
November	2·1	2·1	5·3	5·3	3·7	3·8	1·0	1·5	2·5	2·8	4·0	3·8
December	3·4		6·8		5·0		1·7		3·9		3·1	

Months.	7		8	9		10		11		12	13	14
	°	°	°	°	°	°	°	°	°	°	°	°
January	3·5			0·7		3·6		1·0				
February	3·5	3·5	5·5	3·0	2·2	4·1	4·1	1·3	1·0	2·0	2·5	4·5
March	3·5			2·8		4·6		0·7				
April	4·0			3·1		4·0		0·7				
May	3·5	3·7	0·0	3·2	3·1	4·1	4·4	0·8	−0·3	2·5	2·0	4·5
June	3·5			3·0		5·2		−2·3				
July	2·0			1·9		3·7		−2·5				
August	2·0	1·7	−0·2	2·2	2·5	3·6	4·1	−3·4	−3·4	4·0	2·4	6·4
September	1·0			3·3		5·0		−4·4				
October	1·0			2·6		5·0		−4·1				
November	2·0	1·7	3·8	2·7	2·5	4·9	4·9	−2·8	−2·8	3·1	4·0	7·1
December	2·0			2·3		4·9		−1·5				

COL.
1. Daunt's Rock *minus* Outer Dowsing.
2. Seven Stones ,, ,,
3. Harris ,, Pennant and Fraserburgh.
4. ,, ,, Cove Bay.
5. ,, ,, Uzon.
6. Royal Sovereign ,, Outer Dowsing.
7. Average temperatures on the West Coast in lat. 55° N., estimated from the monthly charts, *minus* similarly estimated temperatures on the East Coast, in the same latitude.
8. Temperatures in lat. 55° N., long. 15° W. (Table III.), *minus* the West Coast temperatures used in Col. 7.
9. Daunt's Rock *minus* Harris.
10. ,, ,, Lerwick.
11. Lerwick ,, Outer Dowsing.
12. Temperatures in lat. 50° N., long. 15° W., *minus* temperatures in lat. 55° N., long. 15° W.
13. Temperatures in lat. 55° N., long. 15° W., *minus* temperatures in lat. 60° N., long. 15° W.
14. Temperatures in lat. 50° N., long. 15° W., *minus* temperatures in lat. 60°. N., long. 15° W.

[illegible] one becomes steeper as summer pro[illegible] suggest that the distribution [illegible] isothermal surface to turn [illegible] west of Ireland and extend[illegible] being higher than the end A by a [illegible] larch [illegible] temperature gradient [illegible] most [illegible] temperature [illegible] summer months [illegible] water in [illegible] where warmer during summer than that [illegible] south-west is greatly increased in [illegible] by the spreading of cold water from the [illegible] North Sea during spring. This distribution, [illegible] course liable to great modification [illegible] shown elsewhere that under special circum[illegible] movement of surface water near the western coasts [illegible]. This would probably have the effect [illegible] temperature gradient.

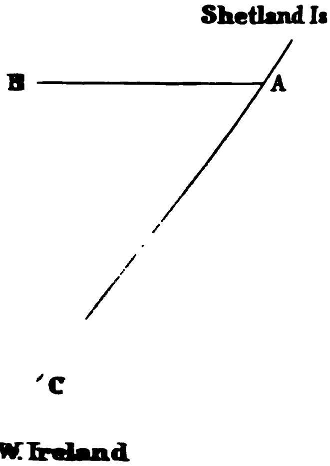


FIG. 14.

[illegible] Temperatures of Air and Sea.

[illegible] compare the mean temperature of air and sea it [illegible] undesirable, to work out special averages [illegible]. The air temperature observations made at the coast[illegible] the light-vessels showed themselves, on [illegible] and could not be trusted to give the real [illegible] observation. Again, supposing them to [illegible] themselves, it by no means followed that they [illegible] purpose, for it is obvious that a station may [illegible] position for observing sea temperatures, and not [illegible] conversely. Finally the period over which [illegible] observations extend is not long enough to give a good [illegible] although the mean for the sea may be fairly [illegible]. The air observations were therefore discarded altogether,

[illegible] Report of the Fishery Board for Scotland, III. p. 280.

BLE V. DIFFERENCES BETWEEN THE MEAN TEMPERATURES OF THE AIR AND OF THE SURFACE WATER OF THE SEA. (Tenths of a Degree Fahr.).

ation.	Air Station.	Height above Sea-level.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year
		ft.													
ıd .	Seaham .	60	+19	+12	+5	−10	−12	−21	*−30*	−19	+2	+11	**+26**	**+26**	+1
ıgh .	Scarborough	159	+25	+10	+17	+2	−2	−17	*−28*	−8	+5	+23	**+28**	**+28**	+7
ead .	Spurn Head	28	+17	+8	+5	−10	−12	−16	*−24*	−15	+4	+23	**+35**	+33	+4
owsing .	(Chart) .	...	+46	+18	−5	−26	−37	−45	*−54*	−35	−4	+31	+53	**+74**	0
ıd Ower	Cromer .	90	+33	+19	−4	−35	−39	*−50*	−38	−13	+10	+34	+54	**+56**	+2
. .	Yarmouth .	12	+21	+3	−8	−28	−35	*−45*	−34	−16	+7	+32	**+47**	+40	−2
ı . .	(Chart) .	...	+25	+3	−6	−25	−22	*−28*	−12	+5	+30	+42	**+54**	+52	+10
dwin .	Ramsgate .	105	+48	+29	+11	−20	−22	*−28*	−20	00	+28	+47	**+82**	**+82**	+19
vereign	Eastbourne	12	+59	+22	+5	−20	−30	*−38*	−18	+3	+27	+58	**+72**	+70	+17
. .	Worthing .	33	+50	+23	+7	−24	−33	*−34*	−16	00	+23	+60	**+73**	+72	+17
; . .	Swanage .	178	+47	+23	+10	−14	−23	*−32*	−22	−4	+20	+50	+61	**+66**	+16
: . .	Prawle Pt. .	350	+24	+17	+15	−3	−5	−16	*−21*	−13	+4	+24	**+42**	+35	+8
ı . .	Falmouth .	183	+35	+29	+28	+6	−9	−29	*−31*	−15	+8	+35	**+47**	+45	+12
. .	Scilly . .	100	**+29**	+18	+27	+17	+12	0	−10	*−13*	00	+13	+28	**+29**	+14
ones .	Scilly . .	100	+40	+30	+22	+4	−11	*−25*	−17	−13	−1	+18	+42	**+43**	+12
and v	Newquay .	100	+4	+8	+7	+4	+7	*−4*	+5	+6	+1	+9	**+21**	+19	+6
and Gds.	Cardiff .	43	+1	−10	−10	−20	−10	*−11*	+18	+20	+33	**+41**	+32	+24	+9
	Gloucester .	100	+5	−10	−8	*−34*	−23	−24	−2	+5	+26	+35	**+45**	+21	+4
. .	(Chart) .	...	+30	−1	−17	−25	−30	*−42*	−16	+9	+29	+43	**+50**	+29	+6
: . .	Pembroke .	150	+29	+22	+22	0	−5	*−27*	−15	−10	+3	+26	+47	**+53**	+12
Bay .	Aberystwith	69	+45	+31	+26	−11	−37	*−52*	−43	−27	+6	+33	+59	**+62**	+7
n Bay .	Holyhead .	45	+41	+27	+12	−17	−32	*−47*	−39	−20	+11	+41	**+62**	+53	+8
l . .	Holyhead .	45	+10	+3	+2	−13	−15	*−19*	−6	−2	+13	+29	**+44**	+24	+6
l Bay .	Liverpool .	30	+22	+2	−5	−27	*−40*	−39	−23	−6	+22	+34	**+47**	+44	+2
Bank .	Pt. of Ayre	106	+15	+12	+10	−11	−18	*−28*	−23	−3	+15	+32	**+40**	+26	+6
. .	Little Ross .	170	*−15*	−10	−5	−7	+10	+9	+15	+17	+11	+12	**+13**	−4	+3
e . .	Corsewall .	112	+10	+12	+6	−5	−1	*−10*	−5	−8	+8	+5	**+21**	+9	+3
. .	Lamlash .	46	+26	+27	+24	+5	+1	*−11*	−7	−2	+10	+21	**+39**	+34	+14
. .	Island Glass	130	**+42**	+22	+23	+3	+2	0	0	*−1*	+8	+30	+36	+38	+18
y .	Stornoway, L.H.	56	+28	+22	**+36**	+26	*+3*	+13	+14	+12	+18	+27	+34	+30	+22
. .	Bressay, L.H.	105	+12	+20	+18	+12	+7	*−6*	−3	+1	+2	+17	**+21**	+15	+10
. .	Kirkwall .	30	+12	+15	+14	+8	0	+11	*−11*	−9	+2	+9	**+25**	+17	+7
. .	Wick . .	87	+46	+39	+23	+1	−9	*−29*	−27	−16	+2	+38	**+61**	+54	+13
. .	Cromarty .	60	+5	−2	+7	−6	−7	+4	−1	+3	−3	+13	**+24**	+10	+4
t and urgh	Kinnaird's Head	120	+9	+6	+10	−5	−14	*−25*	−23	−16	+1	+4	**+18**	+11	−2
l . .	Peterhead .	95	+30	+16	+4	−16	−28	*−41*	−35	−22	+5	+33	**+50**	+38	+3
. .	Aberdeen .	66	+42	+30	+18	−15	−30	*−51*	−41	−29	−6	+23	+60	**+62**	+6
. .	Montrose .	14	+31	+20	+16	−4	−18	*−33*	−22	−17	−3	+15	**+43**	+37	+6
nd .	Burntisland	40	+25	+16	+7	−16	−20	−26	*−28*	−18	+9	+35	**+49**	+39	+6
th .	Eyemouth .	35	+28	+16	+3	−12	−18	*−34*	*−34*	−21	+2	+28	**+53**	+41	+4
k .	Kingstown .	50	+20	+10	−4	−23	−35	−39	*−42*	−29	0	+27	**+50**	+45	−1
g .	Waterford .	100	+51	+34	+25	−8	−30	*−48*	−43	−23	+13	+49	**+76**	+68	+13
.	St. David's	221	+46	+36	+22	−10	−23	*−41*	−38	−29	0	+31	**+55**	+50	+6
Rock .	Roche's Pt.	32	+26	+23	+16	−7	−11	−25	*−29*	−23	+3	+25	**+42**	+41	+7
wnshend	(Chart)	...	+10	+13	**+17**	+8	+7	−1	*−6*	+1	+2	+5	+14	+14	+7
. .	Valencia .	23	*−2*	+3	0	+6	+16	**+21**	+11	+7	+8	0	+5	−1	+6
. .	Foynes .	108	+22	+12	+24	+21	+21	+23	+16	*+6*	+15	+12	+31	**+38**	+21
r . .	,, .	108	+25	+28	+29	+11	+9	*−1*	+15	+15	+20	+23	**+39**	+32	+20
nd .	,, .	108	+28	+17	+20	*+11*	*+11*	*+11*	+12	+13	+27	+27	**+42**	+36	+20
. .	Belmullet .	40	+15	+20	+17	+10	+11	+12	+8	*+3*	+14	+21	**+36**	+29	+17
Point .	,, .	40	*−9*	+10	+13	+21	+37	**+43**	+33	+19	+19	+10	+19	+13	+19
. .	,, .	40	−7	−1	+3	+12	+30	**+42**	+36	+23	+22	+18	+31	+8	+18
s . .	,, .	40	+12	+19	+17	+12	+11	+16	+14	*+8*	+16	+20	**+33**	+26	+17
. .	Mullaghmore	...	+5	+9	+14	+4	+3	+7	*−5*	−3	+6	+3	**+15**	+7	+5
ghy .	Malin Head	230	+17	+10	+6	+1	*−1*	+5	+1	+2	+6	+16	**+33**	+16	+9
. .	Greencastle	70	+21	+18	+10	−8	−14	*−24*	−23	−8	+9	+25	**+31**	+27	+4
ck .	Donaghadee	30	+62	+44	+27	−5	−20	*−45*	*−45*	−26	+18	+52	**+86**	+81	+18

and a number of stations known to afford reliable observations were selected, and arranged in pairs with the sea temperature stations, special regard being had to similarity of position and exposure. In some doubtful cases an air or sea station has been compared with more than one of the opposite class, so as to ensure that purely local influences are eliminated as far as possible.

The air temperatures used have been extracted from the tables recently published by Dr. Buchan, giving the averages for forty years 1856-95. A number of the averages are, of course, differentiated values, but they may be confidently accepted as closely approaching true means. All the temperatures have been "reduced to sea-level" by adding a correction at the rate of 1° F. for every 300 feet of elevation. In the case of Outer Dowsing L.V., Shipwash L.V., Helwick L.V., Castletownshend, no suitable station for comparison exists, and the air temperatures have been estimated from two independent sets of measurements of the charts appended to Buchan's paper.[1] The mean monthly differences between sea (Table I.) and air in tenths of a degree are given in Table V. The + sign indicates that the sea is warmer than the air, - sign the reverse.

The first and most important result is to show that the difference between the mean annual temperatures of sea and air close to the land has been somewhat overestimated. In no case is the mean excess of sea over the air greater than 2°, and a difference of 1°·7 is only reached or exceeded off the west coast of Ireland, in the Outer Hebrides, the North Channel, and on the south-east coast of England. On the south coast of Ireland, south-west of England, and extreme north of Scotland, the difference is about 1°, in the Irish Sea and on the east coast of Scotland about 0°·5, and on the east coast of England still less, the temperature of air and sea being practically the same. The individual differences are obviously affected by local conditions, and in a few of the pairs of stations the comparisons seem scarcely just, but on the whole the results are much more consistent than might have been expected. It appears from Table III. that out in the open sea, *i.e.* in 15° W. long., the differences are much the same in the lower latitudes as near the land—in 50° N. the mean difference is 1°; but as we go north the excess of water temperature becomes greater—in 55° N. it amounts to 3°, about double that on the west coast of Ireland, and in 60° N. to 5°·5.

Table VA. shows the mean monthly differences for six groups of stations, and brings out very clearly the general nature of the change from month to month. The greatest excess of sea over air (heavy type in Tables V. and VA.) occurs almost everywhere in November and December; south of Ireland and south-west of England it reaches a maximum of 5°, west of Ireland of 3°, north-west of Scotland 3°·5, east of Scotland 4°·5 to 5°, east of England 4°, and south-east of England over 7°. The difference in the two months is nearly the same in all cases, but after the minimum, *i.e.* in January, the changes become widely different in the different groups of stations. In all the west coast regions the excess of sea over air diminishes slowly, most rapidly in the south, less so in mid-latitude, and in the north so slowly that in March the difference in north-west Scotland is scarcely less than the

[1] *Jour. Scot. Met. Soc.*, 1898, p. 3.

maximum. East of Scotland the diminution is nearly twice as fast as south-west of England, but east of England and in the Channel the excess disappears altogether in the beginning of March.

TABLE VA.—MEAN MONTHLY AND ANNUAL DIFFERENCES BETWEEN TEMPERATURES OF SEA AND AIR AT CERTAIN GROUPS OF STATIONS. (Tenths of a degree Fahr.)

GROUP.	No. of Stns.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
England, E.	5	+23	+10	+ 3	−16	−20	*−40*	−31	−14	+ 6	+25	**+38**	**+37**	+ 2
,, S.E.	4	+51	+24	+ 8	−20	−27	*−33*	−19	0	+24	+54	**+72**	**+73**	+17
,, S.W. / Ireland, S.	5	+37	+28	+22	− 5	−17	*−34*	−28	−20	+ 2	+27	**+49**	**+50**	+ 9
,, W.	10	+11	+13	+14	+11	+15	+18	+14	*+ 9*	+15	+15	**+28**	+20	+14
Scotland, N.W.	2	**+35**	+22	+30	+15	*+ 3*	+ 6	+ 7	+ 5	+13	+28	**+35**	**+34**	+19
,, E.	3	+34	+22	+13	−12	−25	*−42*	−33	−23	− 1	+24	**+51**	+45	+ 5

In April the sea is still about 1°·5 warmer than the air north-west of Scotland, and about 1° west of Ireland, *i.e.* about half the maximum in both cases; but in all the other districts the differences have become negative, the sea is colder than the air. The differences in the west of Ireland and in the north-west of Scotland during summer seem to require special explanation. In neither case does the air during any month become warmer than the sea, but the difference in north-west Scotland falls to a minimum—almost zero—in May, April and May being specially sunny months in those parts, while the percentage of sunshine remains at a constant low average from June to September. In the west of Ireland the excess of sea over air scarcely falls below 1°, and it remains practically constant all through the summer. The low percentage of sunshine during summer in those regions is probably rigorously confined to the land, and the maxima at Minard, Blacksod Point, and Claggan in June are probably the result of shallow water-heating, the amount of sunshine increasing rapidly even in Dingle Bay and Blacksod Bay: note that the maximum does not occur at more exposed stations like Aran Island or Ballyglass.

In the other four groups the excess of air over sea is greatest in June, and it falls away quickly, disappearing on the east coast of England and in the Channel at the end of August, and south-west of England and east of Scotland in September. The excess of sea over air then increases very quickly in each case to the November maximum.

It is important to compare these variations with the changes in 15° W. long., shown in Table III. The maximum excess of sea over air is greater, and apparently later in high latitudes than in low; thus in 50° N. the difference is slightly greater in February than in November, but in 60° N. the increase is quite marked. In 50° N. the air is about 1° warmer than the sea in August, which seems to be near the time of maximum: in 55° N. the difference amounts to about 0°·5 compared with 1° the opposite way off the Irish coast. In 60° N. the sea remains 1°·5 warmer than the air, compared with 0°·5 in north-west Scotland and equality in Shetland.

Taking into consideration the relations existing between the temperatures of the sea surface and of the air throughout the year and the dates

at which the temperatures themselves, and their differences, attain maximum and minimum values, it seems reasonable to conclude that on the western coasts of the British Isles the mere presence of Atlantic water is more effective in depressing the summer temperature than in raising that of the winter months. The mild winters of our western coasts are not due to the heating of the air by contact with a surface of warm water brought by a current from warmer regions—Table III. indicates that this is a slow process—but to the fact that the air has itself come from these warmer regions, and is charged with abundant moisture, which sets free vast quantities of heat through condensation. With the South-westerly wind comes the drift current, and the temperature of the water is higher than that of the air, because both are moving northward, and the specific heat of the water is the greater: but the warmth of the air and of the water are both the result of the prevailing direction of the wind. The latter is in the first instance determined by the atmospheric circulation as a whole, and only its variations are in any sense controlled by the movements of surface water. Evidence that they are so controlled has recently been adduced by Pettersson, Meinardus and myself; but the widest variations in different years on our western coasts are insignificant compared to the average difference between them and *e.g.* the coast of Labrador.

The part of the British Isles in which the winter climate is most directly influenced by the warm water of the sea is probably the south and south-east coast of England. From October to January the average temperature of the sea is 6° higher than that of the air, and the warm air coming up Channel passes over a surface of uniform temperature: the warm water is not in this case brought by the wind, but as it were sent on ahead of it; hence the south coast enjoys a mild sea wind without the saturation conditions experienced on the western coasts. On the east coast of Scotland it is noticeable that the sea temperature is as much above that of the air as on the south-west of England, but this is the effect of up-welling caused by the prevailing off-shore wind, and it can therefore have little effect on the climate of the land.

It is perhaps forcing the data of Table II. too far, but a comparison of the daily ranges of the air temperature in January and July, as given by Scott and Gaster (*Quart. Jour. Met. Soc.* 1897, p. 278), with the ranges of the surface waters of the sea, indicates that the ratio of the two is (1) practically the same at the two seasons on the western coasts, (2) immensely greater in winter than in summer at Scilly and in the Channel, and (3) greater in summer than in winter on the east coast. This result may be accidental, but it is interesting in view of the conclusion arrived at above.

Note.—In the maps appended, the × shows the position of the stations, the heavy figures the mean temperatures, and the small figures the differences between air and sea temperatures in tenths of a degree Fahr.

DISCUSSION.

The President (Mr. F. C. Bayard) said the Society was indebted to Mr. Dickson for the time and trouble he had expended in the collation of the data, on the results of which the paper was based. In the illustrations that had been shown of the comparative difference between the mean temperature of the air and that of the sea round the British Islands, the differences appeared to be fairly steady and uniform, excepting perhaps in the month of April, when fluctuations seemed common. Probably this was due to local influences. Another point in one of the illustrations which struck him as remarkable was the isolated piece of colouring off Holyhead. This was a peculiar effect, that an area so limited, and subjected to the same conditions as other points on that coast, should exhibit an appreciable difference.

Dr. H. R. Mill said he did not feel prepared to enter into a discussion of the details of the paper, which dealt in a comprehensive way with a subject of considerable magnitude. The paper, being a discussion of data collected by the Meteorological Office and the Coast Guard, could fairly be regarded as a national work, and Mr. Dickson was to be congratulated on the manner in which he had accomplished his part of it. He (Dr. Mill) had studied one aspect of the question in great detail, and this fact, in a way, disqualified him from attempting to criticise the wider discussion of the complete work. In the case of the Abertay Lightship, the observers on which he had at one time instructed and inspected, he had found that when the extreme phases of spring tides coincided with the time of observation there were always great irregularities of temperature due to the tidal currents. Taking the long mean of eighteen years, these differences would probably tend to balance themselves ; but probably it was safer, as Mr. Dickson said, to ignore observations which exhibited any great divergences from the normal. He thought that Mr. Dickson's figures would afford a definite check on the mean temperatures of the health resorts round our coasts, the observations of some of which were apt to be viewed with distrust.

Dr. R. H. Scott remarked that Claggan is in Blacksod Bay, but is in shallower water than Blacksod station, which is at the point of the Mullet, and practically in as open a situation as Ballyglass. He considered that great thanks were due to Mr. Dickson for undertaking the labour of discussing the mass of observations which had been amassed.

Mr. F. J. Brodie said that if any meteorologist other than one of Mr. Dickson's calibre had advanced this idea of the small effect of the sea on the winter climate of our western coasts, it would have been difficult of acceptation. If the theory were correct, it seemed extraordinary that the coast stations on either side of St. George's Channel were 3° to 4° higher than stations a few miles inland. If the sea could no longer be regarded as the important factor in maintaining this difference, to what cause could it be assigned? The atmospheric conditions would be the same, the prevailing wind blowing inland as well as on the coast, and its influences the same. With reference to the great range exhibited on the south-east coast, he thought this was explainable in some degree by the fact that the winters of this portion of England partook of the nature of continental climate, which was in contrast to the temperature of the comparatively warm strip of water forced into the Straits of Dover from the warmer Atlantic. Mr. Dickson had drawn attention to the very small difference between the temperature of the sea and that of the air ; but the observations he had chosen for the latter were all from stations on the coast, otherwise the variation might have been greater.

Capt. D. Wilson-Barker inquired if the observations were made at high or low water, and whether at a uniform depth? He regarded the observations from the lightships as very satisfactory, the men being accustomed to observe with regularity. He could not speak with such certainty of the Coast Guard. With reference to Dr. Mill's remark on the differences caused by the flow of the tide, he (Capt. Wilson-Barker) thought these would become considerably modified when a long period was under consideration. He thought that some information should be given as to the position from which the observations were taken: whether from the end of a pier in fairly deep water or directly on the beach. He congratulated Mr. Dickson on his endeavour to make such a mass of materials available for scientific discussion and use; such a paper could not fail to be of the utmost service to other workers.

Mr. R. Inwards inquired if it was the absolute or comparative temperature that increased up the Channel. In his opinion, observations made in shallow water were not comparable with those made on lightships.

Mr. G. J. Symons remarked that he was surprised to find the differences so small as shown in Table II. He did not think the ordinary Coast Guardsman could be expected to take observations nearer than whole degrees.

Mr. J. Hunter said that for many years he had made comparative observations of the temperature of the air at Belper with that of the river Derwent, and it might not be inappropriate to give a few of the figures. The river observations were made in a favourable place, and the hour of observation was 9 a.m. There were no observations on Sundays or public holidays, as it was not possible to take them comparably with those made on working days. The outcome of 10 years' comparison of the results was:—Mean temperature of the air (made ½ mile from the river observations), 47°·5; mean temperature of the river Derwent, 49°·6; or a difference of 2°·1 in favour of the river. He had made a comparison between air and river temperatures, month by month, for two years, 1894 and 1896, selecting these years because the mean temperature of the air happens to be within 0°·4 of each other: 47°·3 and 47°·7 respectively. He was struck by the large difference during the winter months,—January, February, November, and December,—which reached 4° or 5°, while in the summer months the variation was inconsiderable, January 1894 showing no difference, and July 1896 only 0°·9. He first attributed the results to the warming of the river by the water from the "Meerbrook Sough," which flows into the Derwent a few miles above the place of observation, but subsequent evidence has satisfied him that this factor can have but small influence. The following figures compare the four coldest months and also the four hottest months of the period covered by his observations:—

	Mean Temperature Air.	Mean Temperature River.	Difference.
Cold Months—	°	°	°
February 1885	27·9	36·7	+8·8
January 1881	29·0	38·2	+9·2
January 1885	31·0	37·1	+6·1
December 1892	33·6	39·7	+6·1
Hot Months—			
August 1893	62·4	62·3	−0·1
July 1896	61·1	61·7	+0·6
August 1880	60·9	57·7	−3·2
August 1884	60·7	62·6	+1·9

The difference of −3°·2 in August 1880 cannot be explained by the speaker.

Mr. H. N. Dickson, in reply, expressed the hope that the material in the paper might afford a basis for further investigation of some of the points raised. With reference to the peculiarity in the temperature in the Holyhead region, to

which the President had drawn attention, he thought that it was really due to the scheme of colouring adopted in drawing the maps. The coincidence of the warm-water area in the Channel with the South Coast health resorts, referred to by Dr. Mill, had suggested itself to him. He thanked Dr. Scott for the additional information with regard to the stations on the west coast of Ireland. With regard to Mr. Brodie's remarks, he wished to draw attention to the confusion which existed as to the causes and effects of the phenomena observed. Recent physical, chemical, and biological observations concurred in showing that the drift current from the south-west was not continuous, but varied in different years and at different seasons, and it appeared that its changes and the variations of the seasons were both the results of a common external cause, acting out in the open ocean. Supposing the prevailing winds over these islands to be North-westerly, a strong current from south-west would not produce the climatic conditions now observed. In reply to Capt. Wilson-Barker, he said that each set of observations had been examined in detail on its merits, but it was impossible to obtain definite information as to the mode of taking observations at each station.

Mr. R. Sheward, in a note to the Secretary, said: "With reference to the paper of Mr. Dickson on Sea-Surface Temperatures, I would like to say I have just completed the casting of the daily values for the fifteen years I have taken the temperature at our pier-head (Eastbourne). Among many interesting features brought to light thereby is the double minimum period, the first early in January, then the rise commences, and by the end of January the sea is much warmer; a fall then commences which continues till about the third week in February, when the sea is again at its lowest of 40°·02, for in casting the daily values it runs to the second place of decimals, thus giving two distinct minimum periods. The daily average never falls under 40°, although every winter at some time or other it is under. The lowest ever observed was during the bitter February of 1895, when for six mornings it was at 30°. The highest observed was 70°, and, strange to say, twice on the same date, August 18. I here give the record:—

	16th	17th	18th	19th	20th
August 1884	68°	69°	70°	69°	69°
August 1893	69	69	70	69	68

I have only to add that there is always a good body of water at our pier-head, and throughout my rule has been to derive the temperature from 2 feet below surface."

ON SOME PHENOMENA CONNECTED WITH THE VERTICAL CIRCULATION OF THE ATMOSPHERE.[1]

By Major-General H. SCHAW, C.B., R.E.

[Read May 17, 1899.]

During some years past I have studied the circulation of the atmosphere in the Australasian district comprised between long. 110° and 185° E. and lat. 10° and 50° S., and more particularly in the New Zealand portion of this area. In this study my attention was first drawn to the well-known belt of anticyclones lying here generally over Australia and the North Tasman Sea, and to the remarkably regular succession of antarctic

[1] This paper is abridged from one in *Transactions of the New Zealand Institute.*

cyclones which travel eastwards along the southern margin of the anticyclonic belt, which in their regularity and great extent are very different in type from the occasional tropical cyclones which appear on the northern margin. Probably there is no other district of the earth's surface of similar extent where careful meteorological observations are recorded and published which is so favourable for observing the interaction of cyclones and anticyclones, and where cyclones are so unobstructed in their action, as they are in this open southern ocean.

During the winter months they occur about every sixth day, and in the summer about once in twenty days. Their rate of eastward motion in winter averages from 150 to 250 miles in 24 hours, but when unobstructed they sometimes advance 1200 miles in 24 hours; their progress is somewhat slower in summer. Their extent from west to east often exceeds 1000 miles; from north to south the extent is generally unknown, owing to the lack of observatories farther south than the south of New Zealand, but occasionally their centres are so far north as to show their quasi-circular form, although New Zealand, lying as it does transversely to their line of advance, always distorts their form remarkably.

The onward motion of these cyclones is always eastwards, with a tendency equatorwards whenever a gap occurs in the anticyclonic barrier; but, frequently, irregular extensions of this barrier occur polewards, which arrests the onward progress of a cyclone until the succeeding cyclone overtakes it, when the two cyclones blend into one and force a passage eastwards. Anticyclones do not seem to have a similar inherent eastward motion, but to act more passively. Each succeeding cyclone brings with it, however, on its north-west side, a new anticyclone, and forces on and gradually dissipates the anticyclone on its north-east front.

When, as occasionally happens, an antarctic cyclone moving northwards meets a tropical cyclone moving southwards they repel one another and change their directions, the one to the south-east, the other to the north-east. If, however, the collision occurs when the directions of translation of the two storms are in less direct opposition, they blend together into an eastward-moving storm, just as one antarctic cyclone overtaking another antarctic cyclone blends with it.

The principal questions which naturally arise after studying these and other facts which will be noticed are the following:—

1. What are the causes of these two opposing systems of horizontal circulation, and what are the vertical circulations connected with them?

2. What is the signification of the comparatively high and low barometric readings in the two systems?

3. What is the inherent onward motive force in an antarctic cyclone? The tracks of tropical cyclones are so irregular that probably their laws of onward motion are somewhat different.

4. What is the relation between cyclones and anticyclones?

5. How do cyclones act on cyclones?

In attempting to reply in some measure to the questions above propounded, I can only put forward hypotheses with the reasons which have led me to form them; yet I am not without hope that some of my suggestions may prove to be fruitful when dealt with by other minds with greater knowledge and greater opportunities of verifying them.

Before, however, I attempt to discuss these special questions, it may

be desirable to describe very briefly the general circulation of the atmosphere and its causes.

The three great causes which produce movements in our atmosphere are: heat, gravitation, and the rotation of the earth on its axis.

The equatorial zone of the earth, becoming heated by the direct rays of the sun, heats in its turn the layer of air in contact with it, which expands and rises, and then flows poleward, north and south, whilst its place below is taken by cooler and heavier air moving in from the direction of the poles. This is the first and simplest cause of motion in the atmosphere, and it is the result of sun-heat and the attraction of gravitation.

But the direction of the air-currents thus established is not strictly along meridional lines, for the effect of the earth's rotation is to deflect to the eastward all currents flowing towards the poles, so that they seem to come from the west of north or south, whilst all currents coming from the poles towards the equator appear to move in the reverse direction, from some point to the east of north or south.

The mathematical law which governs this deflection is that in the Southern Hemisphere, between the equator and the poles, any body freely moving over the surface of the earth in any direction appears to be deflected to the left, and in the Northern Hemisphere to the right, the amount of deflection varying directly as the sine of the angle of latitude. Hence the deflection is much greater at the arctic or antarctic circles than it is, say, in the latitude of 40°. This is important for us to bear in mind when we come to consider the probable causes of the motions of the atmosphere in cyclones (or "lows") and anticyclones (or "highs").

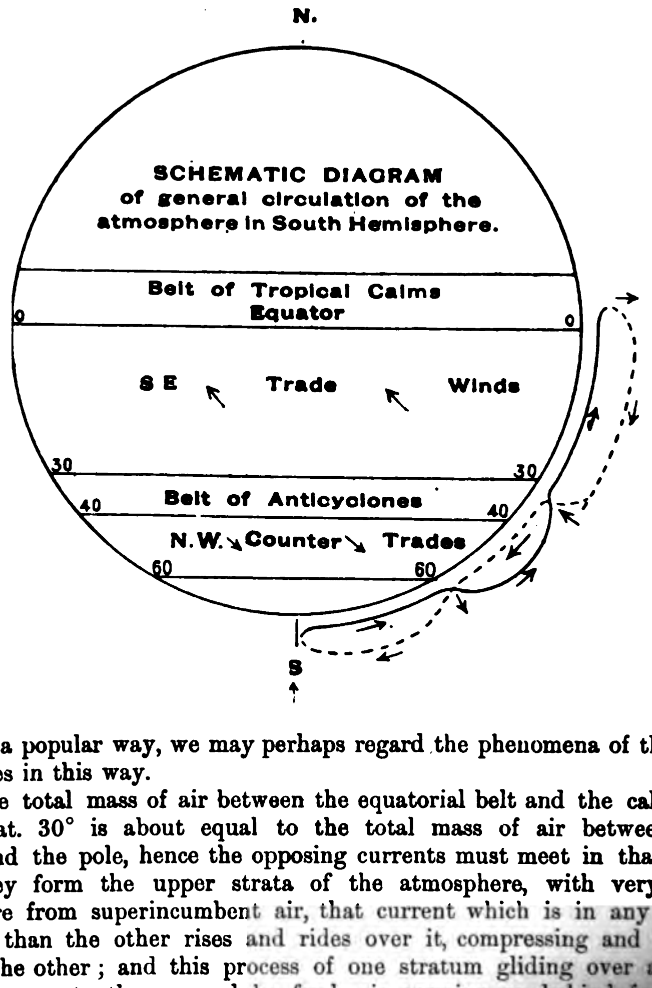
There is, however, another way in which heat influences the motion of the atmosphere, namely, through the agency of the vapour of water, of which a large quantity is always present in the air. The latent heat of this aqueous vapour, when set free by condensation, gives rise in temperate or cold regions to ascending currents similar to those caused by the direct heat of the sun, and this is thought to be one of the main causes of the large storm systems experienced in the temperate zones; while the more violent, but much smaller, tornadoes of tropical regions are believed to be due to an abnormal heating of a portion of the earth's surface and of the air in contact with it.

In addition, therefore, to the constant exchange of air between the polar and equatorial regions, there are the constantly recurring phenomena of circular storms, travelling generally to the eastward in the region of the counter Trades; and also the occasional tornadoes, or hurricanes, met with in the tropics.

The general circulation of the atmosphere, as regards the Southern Hemisphere, is elucidated in the schematic diagram on p. 308. It will be noted that the belt of equatorial calms lies to the north of the equator, and that from this region an upper current flows towards the pole, whilst its place is taken by a cool under current, known as the South-east Trade Wind, which flows in beneath it. At about lat. 35° lies a belt of comparative calm and of high barometrical pressure, and in this region the upper, poleward, current is met by another upper current flowing in the opposite direction towards the equator; another surface current flows out from this region towards the pole, which, becoming deflected to the left, or eastwards, produces the "brave West winds," "the roaring

forties," or the "counter trades," as they are variously termed. Above these Westerly winds a current moving in the reverse direction towards the equator is known to exist, but beyond that our certain knowledge does not extend, although there are strong grounds for believing that the general circulation is completed as shown in the diagram.

No exhaustive theory has as yet been established to account for the gyratory systems of circulation observed in cyclones and anticyclones; but it is clear that they too depend on fixed laws, however complicated these laws may be, and it is also evident that the rotation of the earth governs the direction of their rotation.



In a popular way, we may perhaps regard the phenomena of the a cyclones in this way.

The total mass of air between the equatorial belt and the calm near lat. 30° is about equal to the total mass of air between belt and the pole, hence the opposing currents must meet in that As they form the upper strata of the atmosphere, with very pressure from superincumbent air, that current which is in any d lighter than the other rises and rides over it, compressing and fo down the other; and this process of one stratum gliding over an is being constantly renewed by fresh air pressing on behind fro opposite sides. But this sandwiching of opposing currents and piling up above one another must reduce their onward velocit increase their tendency to deflect to the left, while at th they are being pressed downwards; it follows that as th

uccessive layers of air, after passing over or under the front edges of the pposing layers, are turned to the left and downwards, a downward screwke circulation to the left (or against the hands of a watch) is set up and aintained. The level at which the outflow of air takes place, and the rincipal direction of that outflow, depend on the pressures in the icinity, the principal outflow being towards the centre of lowest ressure. Thus in some measure cyclones are supplementary to antiyclones, forming, as it were, drainage-basins for their out-going air. 'et there is no permanent connection between the two circulations. lather, apparently, does the cyclone attack the anticyclone, which offers more or less passive resistance to its onward movement.

The theory of the cyclonic circulation—of the birth and of the rogress of cyclones such as are experienced in temperate latitudes—is till in its infancy. Yet as the direction of the circulation is invariable n each hemisphere, and as the motion of translation is uniformly to the astward, it is clear not only that the circulation is according to law, but lso that the maintenance of the circulation, and also of the onward march, t may be, are due to some force developed within the cyclone itself.

The origin of a whirlwind in a hot region is simple. Some locality nder special conditions gets excessively heated by the sun, and an pward current is produced. From all sides cooler air flows inwards nd upwards, and so a spiral upward motion is produced, either rightanded in the Southern Hemisphere or left-handed in the Northern Iemisphere. But what is the cause of the cyclonic storms of the outhern Hemisphere, which travel from the west and south? They annot be due to any such superheating of the ground, for all is sea ntil we reach antarctic ice-clad land. As a reply to this question, I put orward the following suggestion, partly derived from the ideas of various riters on the subject and partly from my own ideas.

I conceive that such cyclones have their birth on the confines of the ntarctic region—at the meeting-place of the North-west counter Trade inds with the low-level outflow from the south polar anticyclone. Where these opposing currents meet they cannot glide one over the ther as in the case of the high-level currents which form anticyclones, ecause of the presence of the superincumbent atmosphere; therefore ey form a calm neutral mass between them, and by the constant ressure both are forced upwards, each being deflected strongly in this igh latitude to the left, outside the calm column of air, and so producing e right-handed upward spiral, in which motion the central column self may partake. But as the air ascends temperature and pressure ecrease, until the water-vapour is condensed into rain or snow or hail, nd the latent heat is given up to the surrounding air, which expands nd rises and causes a stronger upward draught. This condensation and iberation of latent heat would be greatly accelerated by the presence of now-clad land at the meeting-place of the winds, and it may be that n some favourable spots on the coast-line of Antarctica high cliffs and laciers meet the force of the vapour-laden West winds and act as the rimary determining influence by forcing the West winds upwards, and y condensation of the vapour and consequent warming of the air, ncreasing the upward current. At the level of the surface of the rozen land the force of the opposite current would be felt, causing first

gyration and then northerly motion of the whole gyrating system, which would be borne eastwards and northwards (equatorwards) by the prevailing Westerly winds—northwards because the southern edge of the storm-whirl is circulating against the West wind while the northern edge is circulating with it, hence the pressure is greater on the south than on the north, and the whole system is forced northwards as well as eastwards. As this upward whirl moves over the ocean it is constantly sucking up water-vapour with the air which enters it below. This is condensed in its turn as it rises into regions of lower pressure and lower temperature, forming clouds, rain, hail, or snow, and liberating more heat, and so giving fresh force continually to the ascending current. The ascending currents must be strongest on the north and east, which are fed by warm air, and less strong on the south and west, which are fed by cold air; and this, probably, is the chief cause of easterly and northerly motion.

In Australasia these cyclones generally first become apparent in the neighbourhood of Cape Leuwin, whence they advance eastwards along the border of the belt of anticyclones, sometimes as rapidly as 1200 miles in the 24 hours, or 50 miles an hour, sometimes much more slowly. Sometimes they are stopped or even recede for a time, apparently being resisted by the anticyclones. Occasionally they partially break through the barrier northwards, but very rarely completely, as far as I have been able to ascertain. Most frequently the centres of the storms pass south of New Zealand; but very frequently they extend as far as Cook Strait, through which they pass. More rarely they extend to the north of the North Island, in which case they generally present the normal type of a completely closed circulation, while those that pass south of Wellington usually present the appearance of a partial circulation open to the south. Probably this is frequently due to our having no observatories farther south to record the variations of barometric pressure and of the direction of the wind; but sometimes the circuit may be open to the south, as is the case occasionally in North America towards the north. Always it is to be observed that the great mountain ranges of New Zealand largely influence the form and progress of the storm circulation, and it would seem also that over the ocean the progress and extension northwards of the depression is much more notable than over the land. This last observation, if established, would seem to favour the view that the inherent force of the storm is due to the vapour of water drawn up from the sea, which gives out its latent heat when condensed in the upper strata of the atmosphere.

Occasionally, the first appearance of one of these depressions is near Tasmania. I have not yet found in the records more than one case where it first appeared in New Zealand. This leads one to suppose that there is some special nursery for storms on the shores of Antarctica, whence one after another is constantly being launched on their ocean voyage.

In the Southern Hemisphere circular storms seem to be more regular and persistent than in the Northern Hemisphere, which probably is due to the smaller interference of land in the former. The Trade winds and counter Trades are more powerful in the Southern than in the Northern Hemisphere. The whole air circulation is freer and more active, and probably this is the main cause of the displacement northwards of the equatorial belt of calms.

Cyclones are generally now called "lows," because the barometer shows a low pressure of the atmosphere towards the centre of a cyclone circulation, and the anticyclones are called "highs" for the contrary reason. It is supposed that when a cyclone borders on an anticyclone the surplus air from the anticyclone pours down into the cyclone, and yet that the circulation within the anticyclone is screwing downwards and that in the cyclone is screwing upwards from below.

We conceive, therefore, that as air-motion depends on gravity (apart from the motion due to the rotation of the earth), the altitude of the plane where the air leaves the anticyclone must be above the level of the plane where it enters the cyclone. The latter appears to be at the level of the earth's surface, and for some unknown height above it. Evidently, if the cyclone is not filled up, and so quenched, the air pouring in must escape upwards and outwards, and this we believe it does, while the anticyclone is replenished by air pouring in from above. Now, if the level of the atmosphere above the anticyclone be above the average level of the atmosphere, what force has caused the surrounding air to rise up and flow down into it? To this I can find no answer in books, although some German meteorologists attribute it to the rotation of the earth. Hence it appears possible that really the true height of the column of air near the 35th parallel of South latitude is below the average, and that the high barometer, or greater atmospheric pressure there, is due to the downward motion of the air rather than to the greater height of the column of air. Similarly it may be that the comparatively low barometer near the equator, and the very low barometer near the antarctic and arctic circles and in the centres of rotating storms, may be due to ascending currents of air there rather than to a lower level of the surface of the atmosphere. Should this be as I suppose—namely, that the general level of the surface of the atmosphere is higher at the equator and towards the poles than it is near the 35th parallel of latitude—the circulation would take place according to the laws of gravity. The velocity acquired by the air sliding down two inclined planes from the equator and polar regions, and meeting about the 35th parallel, would produce the downward movement there, made gyratory by the rotation of the earth.

The friction of one stratum of air gliding over or beside another stratum of air has been found to be infinitesimally small, so that the velocities of two such bodies of air moving from north and south, and meeting about the 35th parallel, would be the final velocities attained by the accelerating force of gravity at this point, and the collision would cause the masses to fall with the momentum produced by the vertical components of their onward and downward motions.

The hypothesis I venture to put forward then is that the high pressure observed in an anticyclone is due—in part at least—to this downward momentum, and similarly that the low pressure observed in a cyclone is due—in part at least—to the upward motion produced primarily by collision of oppositely flowing low-level currents of air, and sustained by the latent heat set free as the vapour of water in the subtropical inflowing current of moist air is condensed by the opposing polar cold current.

If this hypothesis be in any measure true, we ought to observe upward

and downward fluctuations of the barometer corresponding with upward and downward motions of the air.

One practical test suggested itself to me. At the south end of the great harbour of Wellington, New Zealand, rises a steep ridge over which a North wind must rise as it leaves the harbour. The declivity is about 20°, and the top is 640 feet above the water. Evidently a barometer on the ridge will be influenced by an upward motion of the air in a Northerly wind, and, if my view were correct, pressure would be diminished accordingly.

The experiment was tried under varying conditions of force of wind, and it was invariably found that the pressure was always diminished, and so notably in a moderate gale that the height of the ridge was shown to be 760 feet instead of 640 feet as the aneroid correctly showed it in a calm. This experiment showed clearly that if there be vertical circulations in the atmosphere, they must cause marked fluctuations in barometric readings.

Incidentally it explained the cause of many incorrect estimates of mountain heights from barometric readings, and showed the need of calm weather for accurate estimation of heights by atmospheric pressure.

A second practical test was the construction and observation of the movements of a balanced wind vane, so constructed as to point always to the wind both in the horizontal and the vertical direction. Such a balanced wind vane has been fixed in a fairly open situation about 70 feet above the wharf at Wellington, and I have observed it for fifteen months. I have noted from time to time the minor fluctuations of an aneroid placed near the staff of the balanced wind vane. The pressure always increases when the wind motion is downwards, and pressure diminishes when the wind motion is upwards.

In connection with the marked and prolonged rises and falls of the barometer under anticyclonic and cyclonic conditions, my observations show that although this particular locality is somewhat unfavourable owing to the harbour being surrounded by hills rising to 600 or 800 feet high, and to the vicinity of Cook Strait, which both cause local disturbances, yet in the great majority of cases downward currents are indicated by the balanced wind vane under anticyclonic conditions, and upward currents under cyclonic conditions; intermediate weather conditions generally show more or less rapid up-and-down motions like waves, and the inclinations of the waves or inclined currents of air are sometimes as steep as 35°—which is an important fact for engineers, architects, and those who are interested in flying-machines.

I have had another balanced wind vane observed by a friend at Christchurch, New Zealand, for a short time, and the indications were very similar to those observed at Wellington. I am in hopes that, as balanced wind vanes are very simple and cheap, they may be widely introduced in meteorological observatories; and that comparisons of observations with isobaric charts may give much valuable information as to the motions of the lower strata of our atmosphere. The beautiful recording instrument patented by Casella is, I fear, too expensive to be largely used.

If, as I suppose, a "high" means a preponderance of downward motion in the strata of air above the region where it occurs, and a "low" the reverse, and if, in general, a high pressure corresponds with a total

height of the atmosphere less than the normal, while a low pressure corresponds with a total height greater than the normal, our idea of the meaning of an isobaric chart must undergo a change, and we must combine upward and downward motions with the horizontal motions of the wind and conceive of very varied curves of motion in the complicated circulation of the atmosphere.

As regards the interaction of cyclones and anticyclones upon one another, in such cases as are observed in Australasia, it will be evident that, whatever be the full causes of the high and low barometers in the two systems, they tend to destroy one another, the high filling up the low and the low eating up the high, and both being thus reduced towards the normal pressure. But it is a question of supply and demand. When an anticyclone is bordered on both the north and south sides by cyclones it generally is rapidly diminished in extent and pressure, and the "lows" advance towards each other; but if this advance of the "lows" be across Australia they soon shallow and die out—as I conceive, because their inherent force, the constant condensation of vapour of water, is lost in that arid land. Sometimes a large cyclone with very low pressure will rapidly diminish an anticyclone with which it collides; sometimes the regular supply to the anticyclone from above seems to exceed the drain upon it by the cyclone, and it either is undiminished or increases.

Theoretically, if the "high" be north of the "low,"—the most common case in Australasia,—the effect of the outflow from the "high" into the "low" will be to increase the motion eastwards of the latter, owing to the eastward deflection due to the rotation of the earth. If the "high" be east of the "low," the tendency will be to retard the motion eastwards and to deflect the "low" to the south. If the "high" be south of the "low," it will retard its progress; if west of the "low," it will accelerate its progress and deflect it northwards. These theoretical results seem to correspond generally with the facts shown by the weather charts.

To one other point I would draw attention. We have seen that the great circulating systems of depression travel from west to east, and sometimes with great velocity. But the force of the wind does not appear to be influenced by this eastward movement of the systems: the force of the wind depends apparently on the velocity of circulation, not on the rate of translation. We must think, therefore, that the eastward movement of translation, and the corresponding movements north and south of these depressions, are of the nature of wave-motions, not of horizontal motions of the particles of the atmosphere. Such wave-motions are not easily conceived, and they must be very complicated. Fresh particles of the atmosphere are constantly being drawn into the vortex and whirled upwards and outwards as the storm moves on, and the force of the wind depends upon the vigour of this circulation, not on the rate of its propagation.

To reply briefly then to the five questions which I have propounded in the early part of this paper, I would suggest the following answers:—

1. The cause of an anticyclone is the meeting in the higher atmosphere of two opposing currents of air, which, by the action of gravity and the rotation of the earth, descend in a gyratory manner. The cause of an

antarctic (or arctic) cyclone is the meeting in the lower atmosphere of two opposing currents of air, which, by the condensation of water vapour and the consequent liberation of heat, ascend in a gyratory manner caused by the rotation of the earth. The vertical circulation in an anticyclone is from above downwards and from the centre outwards. The vertical circulation in a cyclone is from below inwards and upwards, and from the centre outwards above. In both cases the continuation of the vertical circulation is partially within and partially outside the primary circulation.

2. The barometric indications in the two systems are mainly due to the increase of pressure due to downward circulation, or to the diminution of pressure due to upward circulation, rather than to an increase or diminution of the height of the atmosphere over the localities.

3. The inherent onward motive force in an antarctic cyclone is due mainly to the fact that the ascending currents on the north and east are fed by warm air holding more vapour and liberating more heat than the currents on the west and south, and to the counter Trade current caused by the rotation of the earth; but the onward progress is of the nature of wave-motion, and is quite distinct from the gyratory motion which causes the wind.

4. The relation between cyclones and anticyclones is partly one of supply and demand; the former being fed from below, the latter from above. Usually, but not invariably, the cyclone overpowers the anticyclone, but the direction and rapidity of translation of the cyclone is much influenced by the anticyclone. If the anticyclone be to the north of an antarctic cyclone (the most common case in New Zealand), the rapidity of translation is accelerated; if it be to the east of the cyclone, the latter is retarded. The valley or neutral area between two anticyclones is peculiarly favourable to the motion and development of a cyclone, and often cyclones seem to be generated in these neutral zones.

5. Cyclones which meet when travelling in opposite, or nearly opposite, directions repel one another and change their directions of translation very sharply, but there is a limiting angle within which two such storms coalesce and blend into one circulation. Approximately, the limiting angle is about 120°. These are facts established by observation, but as yet I am unable to put forward a satisfactory hypothesis explanatory of them. I conceive, however, that they may be accounted for when we understand better the nature of the wave-motion which takes place in the onward progress of a cyclone. The meeting of two such waves would produce recoil, while two waves progressing in approximately the same direction would blend.

It is evident that we need more information on the subject of the vertical circulation of the atmosphere. Observations at a number of suitable places of simple balanced wind vanes, such as I have used, will add much to our knowledge of the vertical circulation as it affects the lower atmosphere. Kites, apparently, will be most suitable for searching into the vertical motions of the higher strata, if a recording instrument can be devised for use in connection with them.

Mountain observatories will generally give unreliable results owing to the upward deflection of the currents of air passing over the mountain. The observation of cloud motions is of great value. In studying cloud motions in New Zealand, I have been much confirmed in my suppositio

that vertical circulation of the atmosphere is constantly associated with horizontal circulation, and that these gyratory motions occur on different scales. Smaller circulations in the clouds in the lower stratum of the atmosphere are often seen going on within the larger circulations, which embrace two or more strata, and which seem to me to produce the well-known varying directions in the motions of the upper and lower strata of clouds; while the ascending and descending motions of masses of cloud often observed seem to show the outer limits of these larger vertical circulations.

I hope that the observations and conclusions from them, which I have ventured to put forward in this paper, may lead to discussion amongst experienced meteorologists, and to the ultimate discovery of some of the causes of meteorological phenomena which have hitherto been obscure.

DISCUSSION.

The President (Mr. F. C. Bayard) remarked on the value and originality of the paper, and said that it would be interesting to have the views of our Colonial Fellows on some of the points connected with vertical circulation as observed more particularly in the Southern Hemisphere. This latter fact rendered them difficult of thorough discussion here, where our practical knowledge of the meteorology of those latitudes was limited. Our late respected Fellow, the Hon. Ralph Abercromby, had done much to further the study of Australian meteorology, with his characteristic liberality, by offering prizes for essays on meteorological subjects, and encouraging the advancement of the science in various other ways.

Capt. A. Carpenter thought the paper a very valuable one, opening up several new lines of thought; and he regretted that Major-Gen. Schaw was not present to read it. It was not quite clear whether the author referred to the winter months of the Southern Hemisphere or to our own. If the former, then it seemed strange that tropical cyclones should be common in those months. He should have liked to have seen more information as to the direction of travel of the tropical cyclone, and as to the locality where it met the Antarctic cyclone. The idea that the high cliffs of the coast-line of Antarctica might act as a primary determining influence by forcing the West winds upwards was a new one to him, and seemed not unreasonable. The other suggestion, that they were begun by the meeting of the North-west counter Trade wind with the low-level outflow from the south polar anticyclone seemed possible, and would no doubt ere long be verified by the observations of Antarctic expeditions. The author explained the anticyclone in about Lat. 30° S. as the result of the meeting between two upper currents, one of which flows from the equator towards the pole, and the other in the reverse direction. Owing to the rotation of the earth, they are each deflected to the left, and they press downwards with a screw-like circulation to the left. Major-Gen. Schaw had referred to the desirability of taking wind observations with a balanced vane, but he (Capt. Carpenter) was of opinion that the full effect of the upward air movement would not be obtained by this method. In explanation of question 3, the author gives as a reason for a certain amount of northing in the paths of the cyclones that the prevailing West winds cause more pressure on the south side of the cyclone where they meet the East winds of the whirl. But if this is the case, then we ought to get a southerly tendency in the paths of our North Atlantic cyclones, which is very rarely the case.

Mr. R. H. Curtis said the paper dealt with some phenomena with which we were all familiar, but as to the cause of which none of us knew very much; and since this was an attempt to investigate these causes, he thought the paper was entitled to careful consideration, although we might not be able to agree with the whole of Gen. Schaw's conclusions. In some instances he thought it possible that *effect* had been mistaken for *cause*; as when the author speaks of each succeeding cyclone bringing with it a new anticyclone, and forcing on the latter in its front. Many meteorologists whose opinions are entitled to weight would probably regard as being more likely true the reverse of this statement, viz. that the anticyclone brought with it the cyclone. Similarly, the statement as to what happens when cyclones travelling in exactly opposite directions meet should, he thought, be accepted with a good deal of caution. For himself, although he had had a good deal of experience in studying synchronous weather conditions, he could not call to mind an instance in which such a collision had occurred, and he thought it doubtful whether it ever did; at any rate, it was such an extremely rare occurrence that it scarcely deserved the prominence Gen. Schaw had given to it in the answers to the questions he had propounded in his paper. With the author's remark as to the doubtful character of results obtained from mountain observatories he cordially agreed, but at the same time he thought Gen. Schaw was hardly free from a similar criticism in connection with the exposure of his "balanced vane." The use of such a vane was not now suggested for the first time, but he doubted whether, bearing in mind the extremely small ratio of the vertical movement of the atmosphere to its movement in a horizontal direction, any instrument would be sufficiently sensitive to indicate reliably the vertical component. Certainly such hills as Gen. Schaw said surrounds the harbour of Wellington, N.Z., where the vane had been tried, would introduce eddies of a very complex nature, which it would be impossible to differentiate, and which would quite destroy the value of any indications obtained from a vane only 70 feet above the level of the wharf. A striking example of the extent to which such eddies could make themselves felt, even when caused by much smaller obstructions than the hills which Gen. Schaw described, was afforded by the *Worcester* anemometer experiments, published in the *Quarterly Journal* (page 1). For the purpose of making such observations, probably there was nothing better than smoke, or a long light pennant of narrow ribbon, such as he had himself used for a somewhat similar purpose in connection with anemometer exposure. But in any case a perfectly free and open position, far removed from any obstruction competent to affect the direction of a moving mass of air, was absolutely necessary; and, speaking from his own experience, he believed that, under such conditions, the upward or downward movement would be so slight that no apparatus which had as yet been suggested would be competent to record it.

Capt. D. Wilson-Barker thought Major-Gen. Schaw had good ground for the conclusions he had drawn. He himself had in 1881 read a paper before the Royal Society of Victoria, on "Storms of High South Latitudes," dealing with the horizontal movement. He thought they were controlled largely by the movements of the anticyclones to the north and south of them. He had never met with an instance of two cyclones meeting when travelling in opposite directions, and did not believe such a thing possible. He thought it would be difficult to show the upward movement in cyclones by observing the indications of vanes, etc., as the movement was over such large areas and the gradient consequently very slight; but, in his opinion, its existence was as certain as the downward motion in anticyclones. There was much room for investigations in the vertical movements of the atmosphere. He had himself started many years ago on a similar line of investigation, but was, up to the present, unable to get beyond a certain point. Much more information on the

moisture in the atmosphere and its distribution is required before any progress can be made. He was very glad to hear such a paper read before the Society.

Mr. W. H. DINES (in a note to the Secretary) said he considered this a valuable paper, and on the whole was inclined to agree with the conclusions of the author. There were, however, one or two points which he did not consider tenable. It seemed impossible that differences of the barometer so great as those that occur between cyclones and anticyclones should be produced by ascending and descending currents; for a gale, excluding tornados, hardly ever occurred strong enough to raise the pressure by two-tenths of an inch of mercury on the surface of an object fully exposed to it, and the vertical component of the velocity of a current of air is certainly very slight when compared with the horizontal component. There was no necessity to introduce any such cause, for a difference of 10° in the temperature of a column of air under average conditions was capable of producing a pressure difference of quite ·60 inches of mercury. In addition to this, there was also the centrifugal action of the whirl formed round the cyclonic centre. Another point with which he could not agree was the use of balanced wind vanes. A local downward current in one spot must be balanced by a local upward current in a spot a few yards off. For suppose otherwise for a moment, and that at a height of 50 feet there is a steady downward current over a circle of one mile radius. Let us imagine the region of this descending current enclosed by a telegraph wire 50 feet high running round the circle. The descending air from above must be annihilated within the area, or it must escape under the wire. The first contingency is incredible, and we must fall back on the second; but since the area across which the air is supposed to be entering is 50 times (52·8 exactly) as great as that across which it is escaping, the outward velocity under the wire must be 50 times as great as that of the downward current. Hence, if a downward current strong enough to move the most sensitive vane existed over the whole area, there would also be a very violent outrush of air all along the boundary, and this we know, by observation, does not occur. Similar reasoning shows that the upward velocity of the ascending current in a cyclone is very slight.

ON THE HEAVY FALLS OF RAIN RECORDED AT THE SEVEN OBSERVATORIES CONNECTED WITH THE METEOROLOGICAL OFFICE, 1871-1898.

BY ROBERT H. SCOTT, D.Sc. F.R.S.

[Read June 21, 1899.]

IN the discussion on my paper on "The Frequency of Rainy Days in the British Islands," which appeared in the *Quarterly Journal*, vol. xxiv. p. 217, it was stated that "Calcutta and other Colonial observatories published results in a form that was useful," while the Meteorological Office failed to do so. I have been, as yet, quite unable to discover any official publication emanating from Calcutta, or from any other Indian or Colonial Institution, which contains anything more minute or precise than weekly and monthly totals for individual hours.

The Meteorological Office has for many years published actual hourly values. For 13 years, 1874-1886, the figures have been either litho-

graphed or printed. For 9 years, 1871-80, the hourly records are given graphically in the *Quarterly Weather Report*. From 1887 the only values printed are five-day totals for each hour, and these are now appearing.

I may therefore submit that in the principal libraries in the country there is a mass of material awaiting discussion.

I have been allowed to see a report on Rainfall Statistics for Calcutta, presented to the corporation of that city, by Mr. A. J. Hughes, C.I.E. The returns are analysed for 39 years, but it is well known that in the earlier years no self-recording gauges were in existence. Mr. Hughes has apparently had access to the original tabulations, but he does not attempt to tabulate the indications for intervals shorter than one hour.

I have decided to abide by the hourly tabulations for the 28 years: no records exist before those for April 1871.

I have extracted all instances of falls of rain exceeding 0·25 in. in an hour, and, in addition, various other falls, for different intervals, according to the subjoined scales.

The lower limits are:—

	In.
One hour	0·25
Two hours	0·45
Three ,,	0·65

For longer periods a limiting rate per hour has been adopted, and this is 0·175 ins. per hour, and this gives the following limits:—

	In.
Four hours	0·700
Five ,,	0·875
Six ,,	1·050
Seven ,,	1·225
Eight ,,	1·400

and so on.

I do not see much use in taking an exceptionally heavy fall for a short period, and calculating what that fall would have amounted to if it had lasted for 24 hours. The fact is that this hypothetical quantity did not come down. All the figures to which this paper refers represent amounts which were actually collected at the several stations.

I have not gone back to the original hyetograms, as it is impossible to refer to these for the earlier years. The preparation applied to the paper, to render it waterproof, has, with the lapse of time, dried up and cracked off, so that many of the original records are hopelessly lost.

For the later years, if any one chooses to take the trouble, the actual duration of each shower may be made out. The necessary contraction of the scale, 0·366 in. to an hour, renders any precise fixation of time rather difficult, as the pencil trace is a broadish line.

We have only one instance of an exceptional fall, in a short period, being noticed by the tabulator. At Glasgow, at 5 p.m. August 11, 1895, as much as 0·80 in. was collected in ten minutes.

We have, in the records now under consideration, no fall which approaches an interesting instance to which Mr. Symons has drawn my attention, and which I venture to reproduce, as the account was printed more than half a century ago.

In the *Report of the British Association* for 1846, at p. 17, Mr. G. Dollond, F.R.S., states that, on August 1846, the atmospheric recorder which he had constructed for Mr. Lawson, and which happened to be in action at his own house in Camberwell, registered 3·12 ins. of rain in the space of two hours and seventeen minutes. A thunderstorm was going on at the time. This was certainly an exceptional downpour!

Of falls of an inch or more in a single hour we have six instances:—

In.
1·310 at Falmouth, September 5, 1886, 1-2 a.m.
1·290 at Glasgow, August 31, 1887, 3-4 p.m.
1·054 at Stonyhurst, July 8, 1871, 1-2 p.m.
1·000 at Falmouth, November 7, 1871, 1-2 p.m.
1·000 at Stonyhurst, June 2, 1889, 4-5 p.m.
1·000 at Valencia, September 1, 1885, 2-3 a.m.

Of other exceptional falls the following seem to deserve special notice:—

FALMOUTH . . 2·380 ins. in seven hours, August 27, 1892.
Giving an average of 0·340 in. per hour.
VALENCIA . . 1·700 in. in four hours, July 2, 1873.
Giving an average of 0·425 in. per hour.
ABERDEEN . . 1·610 in. in four hours, October 2, 1895.
Giving an average of 0·402 in. per hour.
ARMAGH . . 1·280 in. in four hours, September 30, 1878.
Giving an average of 0·320 in. per hour.

The subjoined tables give the analysis of all the exceptional falls, which have been extracted for this paper. The actual figures used have been copied, and are handed over herewith to the Society for preservation.

If we examine these tables we shall see that by the rough test of adding together the total numbers of falls for one, two, and three hours respectively, Falmouth heads the list for frequency of heavy falls.

The sum total for Falmouth, for all three intervals, is 416; while at Valencia it is only 369, and at Stonyhurst 342.

It is somewhat remarkable that Kew, despite the comparative dryness of its climate, with a total fall of 24·19 ins. (1866-90), comes out with a higher sum total, 177, than either Aberdeen, 155 (rain for same 25 years 30·93 ins.), Glasgow, 131 (rain 40·21 ins.), or Armagh, 127 (rain 31·45 ins.).

It appears to me that it would be an important matter if engineers could agree as to what information they really desire as to the rain, in regard to the rate and amount of its fall. It seems to be almost impracticable to devise a scheme of publication, at any reasonable cost, of the duration and amount of every shower, separately, on a squally day.

TABLE I.—VALENCIA.

A.—NUMBER OF INSTANCES OF FALLS OF RAIN EXCEEDING ·25 IN. IN 1 HOUR, ·45 IN. IN 2 HOURS, AND ·65 IN. IN 3 HOURS.

Time.	·25-·34	·35-·44	·45-·54	·55-·64	·65-·74	·75-·84	·85-·94	·95-1·04	1·05-1·14	1·15-1·24	1·25-1·34	1·35-1·44	1·45-1·54	1·55-1·64	1·65-1·74	1·75-1·84
1 hour .	146	25	7	5	1	3	...	1	...	...	...	...	...	...	...	...
2 hours .	...	...	78	26	7	5	2	1	3	2	1	...	...	...	...	...
3 „ .	...	...	...	...	27	13	7	1	1	3	2	1	...	1	...	...

B.—Number of Instances in which the Rate of more than ·175 In. per Hour was maintained for 4 or more Hours.

Time.	·175-·184	·185-·194	·195-·204	·205-·214	·215-·224	·225-·234	·235-·244	·245-·254	·255-·264	·265-·274	·275-·284	·285-·294	·295-·304
4 hours .	8	1	2	1	...	...	...	2	2	1	...	...	...
5 ,, .	1	3	2	...	1	1	...	...	...	1	...	...	...
6 ,, .	...	...	2	...	1	...	...	1	...	...	...	...	...
7 ,, .	2	...	...	...	...	...	...	...	...	...	...	...	...
8 ,, .	...	...	...	...	...	...	...	...	1	...	...	...	...
9 ,, .	...	...	...	...	...	...	...	...	...	...	...	...	...
10 ,, .	2	...	...	...	...	...	...	...	...	...	...	...	...

1 in. fell September 1, 1885, at 3 a.m.
An average of 0·425 in. per hour for 4 hours, July 2, 1873. Total, 1·700 in.
An average of 0·169 in. for 9 hours, October 24, 1894. Total, 1·520 in.
An average of 0·170 in. for 10 hours, July 5, 1894. Total, 1·705 in.
An average of 0·153 in. for 14 hours, January 19, 1879. Total, 2·143 ins.

TABLE II.—ARMAGH.

A.—Number of Instances of Falls of Rain exceeding ·25 In. in 1 Hour, ·45 In. in 2 Hours, and ·65 In. in 3 Hours.

Time.	·25-·34	·35-·44	·45-·54	·55-·64	·65-·74	·75-·84	·85-·94	·95-1·04	1·05-1·14	1·15-1·24	1·25-1·34	1·35-1·44	1·45-1·54	1·55-1·64	1·65-1·74
1 hour .	49	15	6	5	...	...	...	2	...	...	...	...	...	...	...
2 hours .	...	...	25	5	3	3	1	1	...	...	.	...	...	...	...
3 ,, .	...	...	...	...	19	1	...	1	...	1	...	...	...	...	...

B.—Number of Instances in which the Rate of more than ·175 In. per Hour was maintained for 4 or more Hours.

Time.	·175-·184	·185-·194	·195-·204	·205-·214	·215-·224	·225-·234	·235-·244	·245-·254	·255-·264	·265-·274	·275-·284	·285-·294	·295-·304
4 hours .	1	...	3	...	...	1	...	...	...	...	...	...	...
5 ,, .	2	...	...	...	...	...	...	...	...	...	...	...	...
6 ,, .	...	1	...	...	...	...	...	...	...	...	...	...	..
7 ,, .	...	...	...	...	...	...	...	...	...	...	...	...	...
8 ,, .	...	...	1	...	...	...	...	...	...	...	...	...	...
9 ,, .	...	...	...	...	...	...	...	...	...	...	...	...	...
10 ,, .	...	...	...	...	...	...	...	...	...	...	...	..	...

An average of 0·206 in. per hour for 11 hours, June 28, 1888. Total, 2·272 ins.
An average of 0·320 in. per hour for 4 hours, September 30, 1878. Total, 1·280 in
An average of 0·136 in. per hour for 7 hours, August 2, 1876. Total, 0·950 in.
An average of 0·169 in. per hour for 8 hours, October 15, 1886. Total, 1·355 in.

TABLE III.—GLASGOW.

A.—NUMBER OF INSTANCES OF FALLS OF RAIN EXCEEDING ·25 IN. IN 1 HOUR, ·45 IN. IN 2 HOURS, AND ·65 IN. IN 3 HOURS.

Time.	·25-·34	·35-·44	·45-·54	·55-·64	·65-·74	·75-·84	·85-·94	·95-1·04	1·05-1·14	1·15-1·24	1·25-1·34	1·35-1·44	1·45-1·54	1·55-1·64	1·65-1·74	1·75-1·84
1 hour .	55	12	6	...	1	...	2	..	...	...	1	...	...	...	...	...
2 hours .	...	...	21	8	3	1	...	1	...	...	...	...	...	...	...	1
3 ,, .	...	...	...	...	12	3	1	...	2	...	1	...	...	...	...	...

B.—NUMBER OF INSTANCES IN WHICH THE RATE OF MORE THAN ·175 IN. PER HOUR WAS MAINTAINED FOR 4 OR MORE HOURS.

Time.	·175-·184	·185-·194	·195-·204	·205-·214	·215-·224	·225-·234	·235-·244	·245-·254	·255-·264	·265-·274	·275-·284	·285-·294	·295-·304
4 hours .	...	...	2	...	...	...	...	...	...	...	1	...	1
5 ,, .	...	...	2	2	...	...	...	...	...	...	...	...	1
6 ,, .	...	...	...	1	...	...	...	...	...	...	...	...	...
7 ,, .	...	1	1	...	...	...	...	...	...	...	...	...	...
8 ,, .	...	...	...	...	...	...	...	...	...	...	...	...	...
9 ,, .	...	...	...	...	...	...	...	...	...	...	...	...	...
10 ,, .	...	...	...	...	...	...	...	...	...	...	...	...	...

1·290 in. fell in 1 hour, August 31, 1887, at 4 p.m.
An average of 0·165 in. for 10 hours, November 13, 1876. Total, 1·649 in.

TABLE IV.—ABERDEEN.

A.—NUMBER OF INSTANCES OF FALLS OF RAIN EXCEEDING ·25 IN. IN 1 HOUR, ·45 IN. IN 2 HOURS, AND ·65 IN. IN 3 HOURS.

Time.	·25-·34	·35-·44	·45-·54	·55-·64	·65-·74	·75-·84	·85-·94	·95-1·04	1·05-1·14	1·15-1·24	1·25-1·34	1·35-1·44	1·45-1·54	1·55-1·64	1·65-1·74	1·75-1·84
1 hour .	54	17	3	4	1	...	...	...	...	...	...	...	...	...	...	...
2 hours .	...	...	28	9	6	5	1	...	...	1	...	...	...	...	...	...
3 ,, .	...	...	...	...	11	7	3	3	...	...	...	1	1	...	...	...

B.—NUMBER OF INSTANCES IN WHICH THE RATE OF MORE THAN ·175 IN. PER HOUR WAS MAINTAINED FOR 4 OR MORE HOURS.

Time.	·175-·184	·185-·194	·195-·204	·205-·214	·215-·224	·225-·234	·235-·244	·245-·254	·255-·264	·265-·274	·275-·284	·285-·294	·295-·304
4 hours .	...	3	...	3	...	...	...	1	...	...	...	...	...
5 ,, .	2	...	...	...	1	...	...	...	...	...	...	...	...
6 ,, .	...	...	...	...	...	...	...	...	...	...	...	...	...
7 ,, .	1	1	...	...	...	...	...	...	...	...	...	...	..
8 ,, .	...	...	...	1	1	...	...	...	...	...	...	...	...
9 ,, .	...	...	...	...	...	...	...	...	...	...	...	...	...
10 ,, .	1	...	...	...	...	...	...	...	...	...	...	...	...

An average of 0·402 in. for 4 hours, October 2, 1895. Total, 1·610 in.
An average of 0·166 in. for 8 hours, August 21, 1877. Total, 1·330 in.
An average of 0·156 in. for 9 hours, November 29, 1877. Total, 1·405 in.

TABLE V.—FALMOUTH.

A.—Number of Instances of Falls of Rain exceeding ·25 In. in 1 Hour, ·45 In. in 2 Hours, and ·65 In. in 3 Hours.

Time.	·25-·34	·35-·44	·45-·54	·55-·64	·65-·74	·75-·84	·85-·94	·95-1·04	1·05-1·14	1·15-1·24	1·25-1·34	1·35-1·44	1·45-1·54	1·55-1·64	1·65-1·74	1·75-1·84
1 hour .	133	39	19	2	3	...	...	1	...	...	1	...	...	...	...	...
2 hours .	...	...	72	38	18	7	5	...	2	1	1	1	1	...	...	...
3 ,, .	...	...	...	...	30	23	5	6	3	1	1	...	2	1	...	...

B.—Number of Instances in which the Rate of more than ·175 In. per Hour was maintained for 4 or more Hours.

Time.	·175-·184	·185-·194	·195-·204	·205-·214	·215-·224	·225-·234	·235-·244	·245-·254	·255-·264	·265-·274	·275-·284	·285-·294	·295-·304
4 hours .	3	3	3	3	...	1	1	1	2	...	1	2	...
5 ,, .	1	1	...	1	1	...	...	...	...	...	2	...	...
6 ,, .	1	1	2	1	1	...	...	...	...	...	...	...	...
7 ,, .	...	1	...	1	...	...	1	...	...	...	...	1	...
8 ,, .	...	...	...	...	...	...	...	...	...	...	...	...	...
9 ,, .	...	...	...	...	...	...	...	...	...	...	...	...	...
10 ,, .	...	...	...	...	...	...	...	...	...	...	...	...	...

1·000 in. fell November 7, 1871, at 2 p.m.
1·310 in. fell September 5, 1886, at 2 a.m.
An average of 0·340 in. per hour fell for 7 hours, August 27, 1892. Total, 2·380 ins.
An average of 0·186 in. per hour fell for 13 hours, October 4, 1880. Total, 2·425 ins.
An average of 0·166 in. fell for 8 hours, November 27, 1898. Total, 1·325 in.
An average of 0·159 in. fell for 10 hours, June 30, 1879. Total, 1·590 in.

TABLE VI.—STONYHURST.

A.—Number of Instances of Falls of Rain exceeding ·25 In. in 1 Hour, ·45 In. in 2 Hours, and ·65 In. in 3 Hours.

Time.	·25-·34	·35-·44	·45-·54	·55-·64	·65-·74	·75-·84	·85-·94	·95-1·04	1·05-1·14	1·15-1·24	1·25-1·34	1·35-1·44	1·45-1·54	1·55-1·64	1·65-1·74	1·75-1·84
1 hour .	122	47	8	2	4	1	...	...	2	...	...	...	...	...	...	...
2 hours .	...	...	60	27	4	4	3	3	...	...	1	...	...	...	...	...
3 ,, .	...	...	...	...	27	13	0	2	4	...	1	1	...	...	...	...

B.—NUMBER OF INSTANCES IN WHICH THE RATE OF MORE THAN ·175 IN. PER HOUR WAS MAINTAINED FOR 4 OR MORE HOURS.

Time.	·175-·184	·185-·194	·195-·204	·205-·214	·215-·224	·225-·234	·235-·244	·245-·254	·255-·264	·265-·274	·275-·284	·285-·294	·295-·304
4 hours .	6	1	1	2	...	1	1	1	...	...	1	...	...
5 ,, .	1	1	2	...	...	...	...	1	1	1	...	...	...
6 ,, .	2	1	...	1	1	...	...	...	...	...	...	...	...
7 ,, .	...	1	...	...	...	...	...	...	...	...	...	...	...
8 ,, .	...	2	...	...	1	...	...	...	...	...	...	...	...
9 ,, .	...	...	...	...	...	...	...	...	...	...	...	...	...
10 ,, .	...	...	...	...	...	...	...	...	...	...	...	...	...

1·054 in. fell July 8, 1871, at 2 p.m.
1·000 in. fell June 2, 1889, at 5 p.m.
An average of 0·380 in. fell for 4 hours, June 29, 1873. Total, 1·440 in.
An average of 0·327 in. fell for 4 hours, March 29, 1877. Total, 1·310 in.
An average of 0·167 in. fell for 6 hours, November 22, 1890. Total, 1·001 in.

TABLE VII.—KEW.

A.—NUMBER OF INSTANCES OF FALLS OF RAIN EXCEEDING ·25 IN. IN 1 HOUR, ·45 IN 2 HOURS, AND ·65 IN 3 HOURS.

Time.	·25-·34	·35-·44	·45-·54	·55-·64	·65-·74	·75-·84	·85-·94	·95-1·04	1·05-1·14	1·15-1·24	1·25-1·34	1·35-1·44	1·45-1·54	1·55-1·64	1·65-1·74	1·75-1·84
1 hour .	69	17	9	3	3	1	2	...	...	...	...	...	...	...	...	...
2 hours .	...	...	19	13	9	5	4	2	...	...	...	...	...	...	...	...
3 ,, .	...	...	...	...	8	4	6	2	1	...	...	...	...	...	...	...

B.—NUMBER OF INSTANCES IN WHICH THE RATE OF MORE THAN ·175 IN. PER HOUR WAS MAINTAINED FOR 4 OR MORE HOURS.

Time.	·175-·184	·185-·194	·195-·204	·205-·214	·215-·224	·225-·234	·235-·244	·245-·254	·255-·264	·265-·274	·275-·284	·285-·294	·295-·304
4 hours .	...	...	...	...	..	1	..	1	...	...	...	...	...
5 ,, .	...	...	...	...	...	...	...	1	...	...	...	...	...
6 ,, .	...	...	...	1	...	...	...	...	...	...	...	...	...
7 ,, .	...	..	...	...	...	1	...	...	...	...	..	...	...
8 ,, .	...	...	...	...	...	...	...	...	...	...	...	...	...
9 ,, .	...	...	..	...	1	...	...	...	...	...	...	..	...
10 ,, .	...	...	...	...	...	...	...	...	...	...	...	...	...

DISCUSSION.

The President (Mr. F. C. BAYARD), in inviting discussion on the paper, which he thought distinctly valuable, remarked that Dr. Scott had undertaken the collation of the data in this manner in consequence of some observations made in the discussion of a previous paper read at one of the Society's meetings. On that occasion some suggestions were made by Mr. Latham as to the manner in which rainfall records should be discussed to be of practical utility to the engineering profession, and he should be glad to know to what extent the results contained in the present paper answered its requirements.

Mr. B. LATHAM said that any information of this nature was both valuable and interesting, but the information did not meet the requirements of engineers. What they particularly wanted was the actual rate at which the rain fell and flowed off the surface. To illustrate what was required, he would take as an example the records of his own self-recording rain-gauge at Croydon for the years 1879-1882. The average rainfall of these four years was 28·4 ins., and the number of rainy days 168. If the average yearly rainfall is divided by the number of rainy days the result gives ·169 in. on each rainy day. So far this indicates nothing to the engineer. But by adding up all the time rain fell and all the quantity that fell in these four years, the average rate of fall was found to be ·065 in. per hour. Now if ·169 in., the fall on each rainy day, is divided by the hourly fall we get the time on each rainy day during which on the average rain falls; and this time spread over all the rainy days shows that in these four years all the rain fell on an average in 18·2 days per annum, which represents the average time rain was actually falling. Knowing now the rate the rain fell, a little calculation would give the quantity per acre, which in the present instance would average 3·93 cubic feet per acre per minute. This quantity was by no means abnormal, and was often vastly exceeded; in fact, an instance in London had been recorded, in the *Minutes of the Proceedings of the Institution of Civil Engineers*, vol. cxxix. p. 71, where the fall had attained more than 20 cubic feet per acre per minute. This was the kind of information engineers needed. It would enable them to make sufficient provision for carrying off the flow of water, and also forearm them and prevent the possibility of their works being damaged. The records from his instrument were satisfactory in every respect: it had worked over 20 years without intermission, and Mr. Symons had published in *British Rainfall* for 1880 the results for the earlier years. If a fall of ·80 in. occurred in a space of ten minutes and then rainfall ceased, it figured in the present paper as having fallen in an hour, which was very misleading to any one requiring actual rate of fall.

Mr. G. J. SYMONS congratulated Dr. Scott on the quality of the data included in the paper, but was considerably surprised to find no record of any really heavy fall of short duration; the extreme case cited in the paper, viz. ·80 in. in 10 minutes, which represents a rate of 4·80 ins. per hour, being frequently exceeded in England. In 1878 he had himself registered, *for a very short time*, the excessive rate of 12 ins. per hour; the total measurements on that occasion being 3·28 ins. in an hour and a half, during 34 minutes of which time no rain fell. Ordinary provision does not suffice to carry off these torrential rains. Usually, after a rate of about 2½ ins. per hour is reached the gulleys become stopped up, if not, as occurred in the case he had quoted, the sewers burst. With regard to the successful comparison of these abnormal falls, it was essential to have some definite scale of time, as entries with two variables, depth and duration, create confusion. He thought that an hour, as adopted by Dr. Scott, was the best. He had extracted the entries of ·25 in., ·35, ·45, etc., occurring in the hour at the various stations, and arranged them in order of precedence. The

results thus obtained were :—Falmouth 28, Valencia 27, Stonyhurst 26, Kew 23, Aberdeen 13, Armagh 12, Glasgow 10. For engineering purposes, he thought the custom of the *Magdeburg Zeitung* might, with advantage, be followed in this country. They do not print their curves for every day, but extract from them the portions which present special features. The Montpelier Observatory Reports also contained records of heavy falls in a diagrammatic form, which he had copied in *British Rainfall* 1893, p. 22 ; and that, in his opinion, was the best way to record exceptional falls.

Mr. R. H. CURTIS said that in dealing with storm rains it was absolutely necessary to take into consideration the duration of the rainfall as well as its intensity, and the difficulty lay in deciding upon the inferior limits of time and rate to be noted, and in combining them in such a way as would give the information really required. A storm in which the rain fell at an exceptionally heavy rate, but which lasted for only a very brief interval, might very possibly prove to be of far less importance, from an engineer's point of view, than another in which the rate was less heavy, but which, lasting longer, produced a much greater quantity of water to be dealt with ; and he would like to know the minimum hourly rate and duration, or what might be regarded as its equivalent hourly amount, and also the minimum daily amount, which the profession considered worthy of special attention ; then the number of times on which these limits has been reached or exceeded could easily be furnished. Referring to the figures which had been quoted by Mr. Latham, he said he understood the hourly rate he mentioned had been obtained by a summation of the amounts of rain and the number of *minutes* occupied in their fall. If that were so, the principle was not dissimilar to that adopted by the Meteorological Office, where, however, the time unit was one *hour* instead of one minute, and, therefore, the amount of rain which fell from, *e.g.*, 1 a.m. to 2 a.m., was taken as the fall for the 60 minutes ending at 2 a.m., although possibly it may have fallen in a very few minutes of the hour. It was interesting to note that at Kew, in the 25 years 1871-95, the average number of rainy days, *i.e.* days during any part of which a measurable quantity of rain (0·01 in.) had fallen, was 168, the same number as Mr. Latham had quoted for Croydon ; the number of rainy hours, *i.e.* hours in which any rain at all had fallen, per annum was 881 ; and the average yearly fall 24·685 ins., giving an average fall of 0·028 in. for each rainy hour. This value was obviously below the mean rate at which the rain had actually fallen, because there must have been many occasions on which the fall had lasted for less than 60 minutes ; and, on the basis of Mr. Latham's figures, it would appear that the actual *duration* was about one-half, and therefore the *rate* about double the values given. There is, however, owing to the limits of the scale employed, a difficulty in dealing with some rain records, such as those caused by slight drizzling rain, when a very low time unit is used ; but if Mr. Latham's time unit of one minute were adopted, he failed to see that it brought one very much nearer to the point which, as he understood the matter, engineers were desirous of arriving at, viz. a knowledge of the rate of fall and duration in exceptional or storm falls, and also of the frequency of their occurrence, and for this purpose he thought the data given by Dr. Scott in his paper was really the most useful which had as yet been published. Referring to a remark by Mr. Symons as to a heavy fall of 3·42 ins. in an hour at Camden Square in 1878 not appearing in the tables given in the paper, he explained that at Kew that particular storm was not experienced, the maximum fall in that year, when there were several heavy falls, having been 0·9 in. in an hour on July 24. The very local character of most of the exceptionally heavy downpours was indeed an important feature, which certainly ought to be taken into consideration when judging of the probability of their occurrence in any particular district.

Mr. R. INWARDS remarked that, with regard to the more intense torrential

rains, it was within the bounds of possibility that the observer was in the neighbourhood of a water-spout, as the record of ·80 in. in 10 minutes could only be described as equivalent to pouring water from a tube. With regard to the prevalence of water-spouts, he confessed he had been in some degree sceptical as to the accuracy of a picture in the possession of Mr. Symons, in which as many as twenty water-spouts were depicted, but he had recently been converted from his scepticism by a conversation with a gentleman who had given him his assurance that he had seen a hundred water-spouts existing at the same time within the limit of vision.

Rev. Dr. J. G. PARKER concurred with previous speakers as to the advantage of actual observations over averages for engineering purposes. It was imperative that the exact record for the particular locality be known. In the Yorkshire valleys, particularly that of the Swale, a heavy shower was followed by a rapid rise in the river, often causing destruction of bridges, etc., when no damage was actually caused by the rain.

Mr. E. D. ARCHIBALD observed, with reference to Mr. Inwards's remark on the possibility of water-spouts being responsible for certain of these torrential downpours, that rain of abnormal power and in no way connected with water-spouts was of common occurrence in the tropics. In illustration, he cited the case of Cherrapunji, in the Khasi Hills, India, where 30 ins. in 24 hours was by no means rare (once 40 ins. occurred in the same time). Approximately, 30 ins. would represent a mean rate of fall of 1¼ in. per hour. These abnormal figures were known to be entirely due to the precipitous character of the country, which tilted up the humid air currents coming from the Bay of Bengal.

Dr. R. H. SCOTT thought that the latter portion of the last paragraph in the paper adequately expressed a reply, viz.: "It seems to be almost impracticable to devise a scheme of publication, at any reasonable cost, of the duration and amount of every shower separately on a squally day." With reference to Mr. Archibald's remark on the rainfall at Cherrapunji, Dr. Scott said that Baron Danckelmann reported in the *Zeitschrift* for May that the record from the Cameroons was strikingly similar, though not quite so great; the topographical peculiarities being almost the same, the hills rising straight up from the sea to a considerable altitude, just as the Khasia Hills did from the plain of Bengal.

A NEW SELF-RECORDING ANEMOSCOPE.

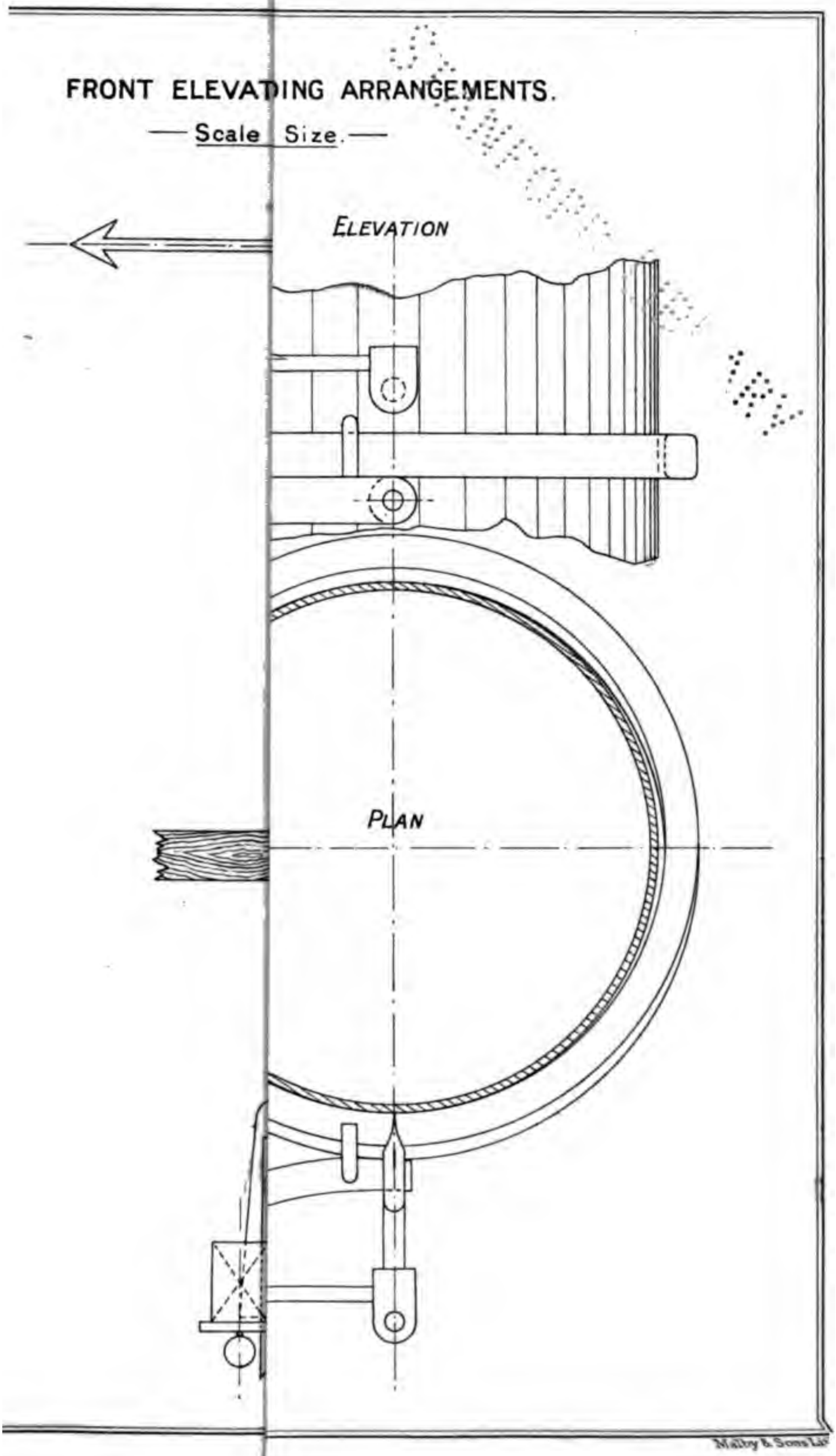
BY JOSEPH BAXENDELL, F.R.Met.Soc.

(Plate IV.)

[Read June 21, 1899.]

VERY various devices have from time to time, and in different countries, been resorted to for the purpose of securing continuous records of the variations in the Direction of the Wind. Few of these, however, have given even moderate satisfaction, and fewer still can be said to have come into general use. In the United Kingdom, during recent years, the trace, in the majority of cases, has been produced by the action of a silver or brass helix or spiral on a sheet of the so-called "metallic" paper first introduced by Messrs. de la Rue & Co. In a more limited number of instances graphite pencils were employed (three frequently being required). Recently, however, MM. Richard Frères and others

PE.


FRONT ELEVATING ARRANGEMENTS.
— Scale Size. —
ELEVATION
PLAN
Malby & Sons Lith

have constructed instruments in which electrical methods of registration are adopted, and with which "beak-pens" may be used.

Having for some time had in action at the Marshside Station of the Fernley Observatory, Southport, one of Dines' Pressure-Tube Anemometers, and being impressed by the various peculiarities in the pressure of the wind delicately and clearly shown by it by means of Mr. R. H. Curtis' excellent fine-pointed anti-friction pen arrangement, it appeared to me that it would be of much interest to secure a similar record of the Direction of the Wind; for neither the spirals, the ordinary pencils, nor the beak-pens furnish traces sufficiently fine and distinct to show the brief or short-period, but very definite, variations in the direction of the wind which undoubtedly exist even in the most open situations, and form a feature quite apart from the momentary gusty oscillations, and which go far to determine the nature of the wind blowing at the time. Moreover, the rapid and instructive movements of the wind in azimuth during thundery weather are frequently recorded but imperfectly.

By the electrical recorders the direction of the wind is, as a rule, given merely to the nearest principal point of the compass; and in practical use these instruments possess various other disadvantages.

Finally, in almost all the older Anemographs the direction apparatus is associated with that for recording velocity or pressure; and the introduction of Mr. Dines' admirable Pressure-Tube Anemometer in many quarters where no Beckley, Osler, or other similar instruments are in use, rendered a simple Direction Recorder a desideratum, a continuous record of direction being almost as important as one of velocity, both in connection with several lines of research and for various utilitarian purposes.

I therefore venture to submit to the Society the following description of a new Wind Direction Recorder, or Self-Recording Anemoscope (Plate IV.), which I designed last year, and which has now been in use at Marshside, Southport, and has acted quite satisfactorily, for several months:—

An exceedingly light, but large, double-bladed spread-vane[1] (the result of experiments made by me with several vanes of various descriptions and sizes) is mounted on an also light (thin, tubular), long steel spindle, the entire weight of both vane and spindle being carried on ball-bearings placed a short distance below the vane and in turn supported by a 2-inch gas-barrel iron pillar enclosing the spindle and resting on a flange bolted to the roof of the substantial hut containing the recording portion of Dines' Anemometer. The vane is upwards of 30 feet above the roof of the hut, and could be fully 40 feet without injuriously affecting the action of the instrument; it is convenient to fix it five feet or so lower than the vane of Dines' Anemometer. The pillar is guyed at two points in its height by sets of three steel wire ropes connected to anchors through the medium of screw-tightening and adjustment hooks. Inside the building a Hook's joint is provided, and also square slipping pieces (in view of contraction and expansion of the long spindle). The spindle, near its lower extremity (which terminates

[1] The blades, which are of aluminium, are 2 feet 6 inches in length (measured from the axis of the vane), and are 15 inches in width at the tips; the angle of divergence is $22\frac{1}{2}°$.

in a suitable bearing), is encircled by a drum rotating with it, on which the chart is wrapped, one end of the paper (from which that particular margin has been cut off) simply overlapping the other end, the join being at "North" on the chart. The drum is steadied by a simple bracket-bearing placed immediately above its upper end and constructed of patent Magnolia antifriction metal. The chart-sheet is secured by circular spring clips at the top and bottom of the drum. A Dines' Anemometer pen is carried on a stout vertical rack of sufficient weight to drive the clock by which its descent is regulated. Attached to the rack, and immediately underneath the penholder, is a short brass arm extending to or past the centre of the face of the drum, and passing fairly close to it. On this arm rests the front of a solid bevelled metal ring, which, slipping *loosely* over the drum, encircles the chart; the back of the ring therefore, by its own weight, falling somewhat lower than the front, thus keeping the overlapping end of the chart (*i.e.* the join) tight and neat, especially when opposite the pen, no matter in which direction the drum is revolving. I have found that a ring can be made which does not add perceptibly to the friction, and yet acts extremely well. A small hook is, however, attached to the arm to prevent all possibility of the ring sticking at any time.

Mr. Curtis's pivoted pen will pass over the simple overlapping joint of the chart under these circumstances perfectly, in either direction, provided only that the chart is so wrapped on the drum that the exterior edge of the joint does not (when in the neighbourhood of the pen) face the penholder's axis, but is in the opposite direction, and of course the charts are printed accordingly and are suitably cut.

Arrangements are made to secure rigid and permanent accuracy in regard to orientation; but facilities are provided for disconnecting the drum when changing the charts, and for lubricating and cleaning each of the bearings.

The instrument, while sensitive even in light airs, is very steady in the strongest gales. A damping arrangement, such as that adopted by the Meteorological Office, can readily be added, however, if desired, and in indifferently exposed positions would probably be important; but with a thoroughly open exposure, and my vane, I find that damping is not requisite in any weather, and I venture to submit to the Society a few specimen records obtained without it, including one during the heavy gale of January 12, 1899. And, indeed, the unrestricted oscillations prove to be extremely interesting, markedly varying as they do in a variety of ways according to the precise type of weather prevailing, and being, except during gales, often more pronounced in character than the somewhat similar variations of wind force.

I need hardly add that both the time and direction scales, or either of them, could be much reduced if desired; but the open scales possess important advantages, and the time scale at present adopted is identical with that of Dines' Anemometer charts, thus facilitating comparisons between the records of direction and force.

DISCUSSION.

The President (Mr. F. C. BAYARD) considered the Fellows were indebted to Mr. Baxendell for placing before them a description of his new and ingenious instrument, though he did not think a clear and lucid understanding of the method of working could be gained from the illustration before them.

Mr. W. MARRIOTT said that last year he had an opportunity of inspecting this instrument at Southport, and had taken a photograph of it, which he showed to the meeting. The anemoscope was mounted on the top of the Marshside Fog Bell Station, the head of the vane being slightly lower than that of the Dines' pressure-tube anemometer. It had worked extremely well, and the records were very interesting. One distinct advantage was the large scale, which showed up the more minute details and features, which would otherwise be lost.

Mr. E. D. ARCHIBALD thought the use and study of the records of the instrument would tend to advance our knowledge of the internal motion of the air by showing the little vortices that are present in almost every wind blast, which would not only extend our meteorological knowledge, but would also be of immense value to those interested in aeronautics. In his opinion, a great many air movements were not straight-line movements; and the constant changes in the wind direction exhibited in the diagrams were a record of these vertical movements added to or subtracted from that of the general forward motion of the medium in which they occurred.

Mr. R. H. CURTIS said the records of wind direction obtained from this instrument were certainly by far the best he had ever seen. The casual movements in azimuth of the vane were well shown, but they were very slight, and in that respect they fully bore out the statement he had often made, as the result of his own close observation, that, given a proper exposure for a vane,—one free from the disturbing influence of houses or other artificial obstructions,—there was no need for applying to it anything in the nature of a brake; and he believed it was because of his views on this point that Mr. Baxendell had decided to dispense with a brake in the instrument now before them. The very open scale also allowed another very interesting feature to be exhibited, viz. an oscillation of quite a different kind to the casual movements he had just referred to, in which the wind slowly, but steadily, veered and backed through a small arc, the total oscillation occupying something like half an hour or thereabouts, and being very similar in general appearance to the long-period oscillations in force shown in the records of the pressure-tube anemometer. It seemed possible that some kind of connection between these two oscillations might eventually be traced. He said that in the vanes of all the anemometers used by the Meteorological Office some sort of 'damping' arrangement was adopted, and it was necessary to do so when the instrument was erected upon the roof of a building. But it was to be feared that one result of its use was to destroy features of the phenomena of aerial dynamics which it was desirable to record, and which were shown very satisfactorily in Mr. Baxendell's curves.

THE AVERAGE HEIGHT OF THE BAROMETER IN LONDON.

By R. C. MOSSMAN, F.R.S.E., F.R.Met.Soc.

[Read June 21, 1899.]

In Mr. Eaton's second paper on "The Average Height of the Barometer in London,"[1] the mean monthly and annual air pressure is given for 100 years, the periods being 1774-1780 and 1787-1879, there being thus a hiatus in the observations extending from September 1781 to December 1786. Having recently had in my possession a number of old manuscript books containing meteorological observations taken in the vicinity of London, I reduced the barometric observations made from 1776 to 1792, with a view of supplying the deficiency in Mr. Eaton's table. The data discussed were observed by Hoy at Muswell Hill from January 1776 to April 1782, and at Sion House from May 1782 to 1790, while the values given in Bent's *Meteorological Journals* were also utilised from 1785 to 1792. As regards Hoy's observations, there was no attached thermometer, so that the readings could not be reduced to 32°, but Bent gives values which are doubtless close approximations to the temperature of the room in which the barometer was hung.

I regret that the anomalies and discordances disclosed by an inspection of the reduced sea-level pressures are so numerous that I do not feel disposed to fill in the blank in Eaton's table. The most consistent observations were those taken by Hoy at Muswell Hill, but they unfortunately come to an end in April 1782, when he removed to Sion House. I have utilised the means for the last four months of 1781 in order to complete the returns for that year in Mr. Eaton's table. The means were September 29·940 ins., October 30·168 ins., November 29·828 ins., and December, 29·852 ins., giving, combined with Eaton's values, a mean (January to August) for the year 1781 of 29·995 ins.

Mr. Symons having kindly sent me an abstract of the 9 a.m. and 9 p.m. observations made at Camden Square from 1880 to 1898, mean monthly pressures for 120 years are now available. Thanks to Mr. Eaton's herculean labours, the results are thoroughly comparable for the whole period, as explained by him in his two papers communicated to the Society. Table I. shows the mean monthly and annual barometric pressures at Camden Square from 1880 to 1898, corrected and reduced to 32° and sea-level, the hours of observation being 9 a.m. and 9 p.m.: the values are also corrected for diurnal range. These corrections, which were based upon the reduction of hourly observations taken at Kew[2] for 22 years, are as follows:—

Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
·008	-·007	-·009	-·010	-·009	-·007	-·007	-·009	-·010	-·010	-·008	-·008	-·009

It may be here stated that the results would have been the same whether the Kew, Greenwich, or Camden Square observations had been utilised, the mean monthly values for the three places being identical. Table II. shows the decennial means for 10 complete decades, as well as means for the 120 years 1774-1781 and 1787-1898. The annual mean

[1] *Quarterly Journal Roy. Met. Soc.* vol. xi. p. 191.
[2] *Journ. Scot. Met. Soc.* vol. xi. p. 41.

TEMPERATURE AND DIURNAL RANGE, AND REDUCED TO SEA-LEVEL.

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.
1880	30·370	29·791	30·103	29·865	30·081	29·900	29·886	29·978	29·970	29·869	29·955	29·912	29·973
1881	29·876	29·825	29·891	29·937	30·091	29·965	29·984	29·837	29·869	29·997	29·946	29·988	29·942
1882	30·354	30·209	30·006	29·763	30·060	29·913	29·880	29·922	29·872	29·840	29·705	29·672	29·933
1883	29·912	30·093	29·937	30·014	29·968	29·979	29·869	30·023	29·835	29·987	29·844	30·174	29·969
1884	30·103	29·931	29·948	29·834	30·009	30·045	29·967	30·025	30·026	30·083	30·171	29·888	30·002
1885	29·903	29·727	30·092	29·801	29·815	30·046	30·186	29·982	29·902	29·717	29·911	30·214	29·941
1886	29·662	30·135	29·976	29·925	29·933	29·989	29·925	29·996	30·033	29·792	29·892	29·702	29·913
1887	30·012	30·334	30·071	30·005	30·012	30·197	30·047	29·987	29·938	30·092	29·715	29·856	30·022
1888	30·238	29·972	29·612	29·886	30·062	29·932	29·772	30·009	30·153	30·073	29·806	29·999	29·959
1889	30·181	29·904	29·988	29·740	29·838	30·035	29·933	29·891	30·056	29·694	30·225	30·198	29·973
1890	29·940	30·185	29·845	29·827	29·854	29·996	29·912	29·897	30·157	30·104	29·872	30·034	29·968
1891	30·147	30·473	29·820	29·978	29·790	30·027	29·947	29·822	30·017	29·779	29·856	29·981	29·969
1892	29·871	29·813	30·028	30·015	30·004	30·011	30·019	29·928	29·985	29·719	30·060	29·997	29·954
1893	30·068	29·720	30·145	30·170	30·067	30·017	29·909	30·041	29·875	29·927	29·99	30·018	29·995
1894	29·876	30·059	29·981	29·879	29·943	30·015	29·895	29·932	30·129	29·918	29·98	30·023	29·969
1895	29·699	30·090	29·738	29·910	30·082	30·073	29·884	29·922	30·152	29·849	29·89	29·806	29·924
1896	30·359	30·331	29·813	30·155	30·227	29·940	30·017	30·025	29·761	29·729	30·132	29·784	30·022
1897	29·887	30·106	29·682	29·860	29·972	30·023	30·018	29·834	30·096	30·180	30·190	29·954	29·983
1898	30·329	29·948	29·886	29·919	29·835	29·993	30·110	30·019	30·110	29·836	29·854	30·080	29·993

TABLE II.—BAROMETRIC PRESSURE IN LONDON—DECENNIAL MEANS.

Period.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.	Range.
	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.
1791-1800	29·941	29·980	29·998	29·893	30·002	30·012	29·972	30·007	29·933	29·897	29·872	29·905	29·951	0·140
1801-1810	29·862	29·946	30·001	29·959	29·961	30·069	29·926	29·962	30·012	29·953	29·826	29·778	29·938	0·291
1811-1820	29·929	29·903	29·946	29·939	29·898	29·992	29·960	30·002	30·035	29·818	29·935	29·902	29·938	0·217
1821-1830	30·047	30·041	29·967	29·893	29·974	30·033	29·953	29·959	29·938	29·947	29·924	29·893	29·964	0·154
1831-1840	30·004	29·936	29·973	29·974	30·002	29·944	29·995	29·965	29·919	30·002	29·847	30·024	29·965	0·177
1841-1850	29·951	29·923	29·963	29·874	29·955	29·983	29·970	29·962	29·996	29·851	29·897	30·010	29·945	0·159
1851-1860	29·907	30·013	29·993	29·954	29·930	29·954	29·985	29·962	30·012	29·894	29·968	29·957	29·961	0·119
1861-1870	29·925	29·996	29·838	30·030	29·983	30·034	29·986	29·974	29·960	29·906	29·953	29·990	29·965	0·192
1871-1880	29·994	29·939	29·953	29·872	29·988	29·950	29·945	29·934	29·949	29·898	29·885	29·942	29·937	0·122
1881-1890	30·018	30·032	29·937	29·873	29·964	30·010	29·948	29·957	29·984	29·938	29·909	29·972	29·962	0·159
Range .	0·185	0·138	0·163	0·158	0·104	0·125	0·069	0·068	0·116	0·184	0·142	0·246	0·028	...
Means 1774-1781 1787-1898 (120 years)	29·965	29·972	29·955	29·933	29·969	29·997	29·964	29·972	29·973	29·910	29·907	29·943	29·955	0·090

was 29·955 ins., being highest (30·075 ins.) in 1834 and lowest (29·813 ins.) in 1872, showing a difference of 0·262 in. in the annual means. The highest monthly mean was that of June, which is 29·997 ins., and the lowest that of November, which is 29·907 ins.; there being thus a difference of only 0·090 in. between the highest and lowest monthly means.

The highest mean pressure of any month (see Table III.) was 30·473 ins. in February 1891, and the lowest was 29·490 ins. in December 1876, the difference being 0·983 in. The month showing the greatest range among the means is February, the highest as already stated being 30·473 ins. in 1891 and the lowest 29·499 ins. in 1776, a difference of 0·974 in. The least variation is in May, the highest mean being 30·227 ins. in 1896, and the lowest 29·790 ins. in 1796, 1817, and 1891, a difference of 0·437 in.

TABLE III.—Highest and Lowest Mean Barometric Pressures in London during 120 Years, at 32° and Mean Sea-Level.

Months.	Highest.	Year.	Lowest.	Year.	Range.
	ins.		ins.		ins.
January	30·387	1779	29·581	1800	0·806
February	30·473	1891	29·499	1776	0·974
March	30·374	1854	29·575	1876	0·799
April	30·308	1817	29·590	1829	0·718
May	30·227	1896	29·790	1796, 1817, 1891	0·437
June	30·234	1826	29·733	1852	0·501
July	30·240	1800	29·706	1816	0·534
August	30·181	1778	29·731	1860	0·450
September	30·246	1865	29·692	1839	0·554
October	30·269	1830	29·573	1812	0·696
November	30·337	1805	29·537	1810	0·800
December	30·423	1843	29·490	1876	0·933
Year	30·075	1834	29·813	1872	0·262

Postscript (added October 23, 1899).

Since this paper was communicated to the Society, I have had occasion to examine critically the old observations about the accuracy of which I at the time expressed considerable doubt. A careful examination of the temperature, winds, and other meteorological phenomena at London and Edinburgh for the years covered by the hiatus in Eaton's table, led me to the conclusion that the anomalies were not due to instrumental defects, but to an inversion of the normal barometric conditions. Thus, during the years 1783, 1784, and 1785, the mean annual barometric pressure was higher in Edinburgh than in London, with a marked excess of Easterly and North-easterly winds at the northern station. The mean monthly and annual barometric pressure for the five years 1782-1786 will be found in the following table. I believe that these means give close approximations to the true average pressure of the air for the period under consideration.

MEAN PRESSURE OF THE AIR IN LONDON AT 32° AND SEA-LEVEL, 1782-1786.

ars.	Jan.	Feb.	Mar.	Apr.	May	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.
82	29·928	30·025	29·841	29·665	29·679	29·920	29·830	29·834	30·109	30·048	30·055	30·217	29·921
83	29·717	29·929	29·845	30·157	29·756	29·751	29·833	29·800	29·662	29·894	29·734	29·761	29·820
84	29·866	29·753	29·663	29·706	30·053	29·843	29·892	29·961	29·960	30·044	29·842	29·674	29·872
85	29·816	29·777	30·014	30·081	29·988	30·089	29·841	29·798	29·756	29·909	29·832	29·878	29·898
86	29·550	29·939	29·752	29·865	29·971	29·914	29·987	29·857	29·821	29·980	29·807	29·752	29·950

DISCUSSION.

The President (Mr. F. C. BAYARD) said the thanks of the Society were due to Mr. Mossman for the labour he had expended in the compilation of the paper. He thought the results would have been rendered even more valuable if the observations had been available for any one place over the whole period, rather than those for a series of years at various places as far apart as Muswell Hill in the north of London and Greenwich in the south-east.

Mr. R. H. CURTIS said that in unreservedly accepting observations made with instruments in use during the latter half of the last century and beginning of this, and in combining them with the values obtained in more recent years with instruments of great precision, one ran a considerable risk of importing an element of doubt into the results obtained from the latter. He knew nothing of the particular instruments employed in making the observations for the earlier years of the period covered by Mr. Mossman's means, or of their heights above mean sea-level ; and while of one barometer it was recorded in the paper that it possessed no attached thermometer, it was highly probable that others may have had large scale errors, and have been very indifferent instruments in other respects (?). Taking these circumstances into consideration, he did not think all the observations for the period were strictly comparable. But, apart from this, he doubted whether any advantage would follow from getting these averages for periods of extreme length. Means for short periods may differ considerably, and perhaps in the case of two five-year means of pressure a difference of as much as three-tenths of an inch might be looked for, although he did not think that limit would be exceeded ; but when we combine a few of these periods the mean value greatly improves, and with a mean of 25 years he thought we came very near indeed to the bed-rock of truth. It was perhaps ungracious to question the utility of work upon which so much labour and time had been expended, but he feared in this case it could not be such as to repay Mr. Mossman for the large expenditure of both which he had undoubtedly bestowed upon the preparation of the tables contained in his paper.

Mr. E. D. ARCHIBALD concurred with previous speakers as to the comparatively greater value of means for a shorter period than that covered by the observations in the present paper. For synoptic purposes and charts it was not so necessary to consider general means. A decennial mean would do quite as well where relative values alone were required.

Mr. G. J. SYMONS partly sympathised with Mr. Curtis' criticism, but thought, on looking at the decennial means, that there was little reason to impugn them, a difference of eleven-thousandths only being exhibited between the first and last ten years of the period, the value for the former being 29·951 ins. and the latter 29·962 ins. He did not think that the fact of the observations being made at different places within the metropolitan area would seriously affect

the results; for, when reduced to sea-level, they ought to exhibit no greater divergency than a few thousandths of an inch, all the stations being within an area of ten square miles. In the case of statistics of rainfall, temperature, etc., the difference of locality would be a serious consideration, but as regarded sea-level pressure he thought that it was of little moment.

THE PRESIDENT'S "AT HOME,"

70 Victoria Street, Westminster—May 16, 1899.

In order to welcome the Fellows to the New Offices of the Society, the President, Mr. F. C. Bayard, held an "At Home" on the above date from 8 to 10.30 p.m. As stated in the Report of the Council (p. 208), these Offices comprise the whole of the second floor at Princes Mansions, 70 Victoria Street, Westminster. A plan of the rooms is given in the accompanying illustration.

During the evening there were two Demonstrations by the Optical Lantern in the Meeting Room, viz. (1) at 8.45 p.m. an exhibition of slides from the Society's collection; and (2) Mr. W. Marriott exhibited some slides illustrating sights which he had witnessed.

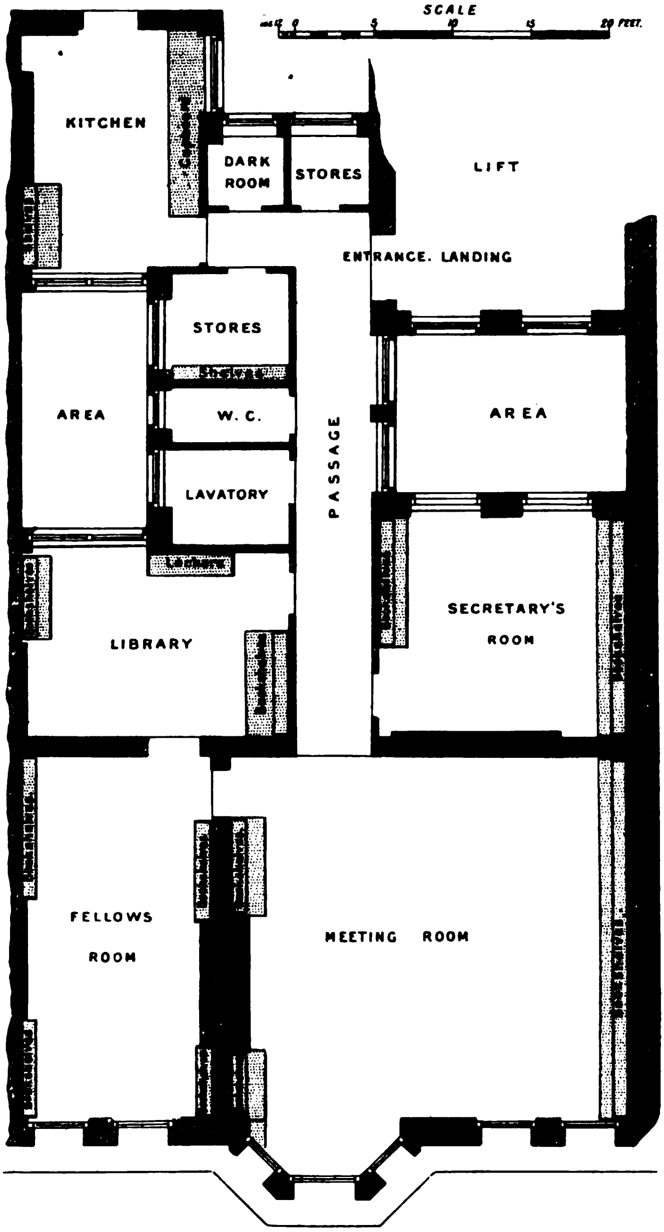
Refreshments were served in the Secretary's Room.

An interesting Exhibition of Instruments, Photographs, etc., was arranged in the various rooms, and remained open till the end of the week.

CATALOGUE OF EXHIBITS.

Entrance Hall.

1 Plan of Rooms, second floor, 70 Victoria Street.
2 The Frozen Thames, February 1895 (five photographs).
3 Photograph of Hail Stones (actual size) which fell at Richmond, Yorkshire, July 8, 1893.
4 Portrait of Luke Howard, F.R.S.
5 Condition of the river at Oxford, February 1895.
6 Portrait of Henry Perigal, Treasurer, Royal Meteorological Society, 1853-1898.
7 International Meteorological Congress, Rome, 1879.
8 Diploma awarded to the Royal Meteorological Society by the Congress of Climatology and Hydrology, Biarritz, 1886.
9 Diploma awarded to the Royal Meteorological Society at the International Health Exhibition, London, 1884.
10 International Polar Congress, Vienna, 1884.
11 International Meteorological Conference, Munich, 1891.
12 Portrait of John Lee, LL.D., F.R.S., President, Royal Meteorological Society, 1855-6.
13 Boston Church, Lincolnshire (west view).
14 International Meteorological Conference, Upsala, 1894.
15 Temple of the Winds, Athens.
16 International Meteorological Conference, Paris, 1896.
17 Boston Church, Lincolnshire (south-east view).
18 International Meteorological Conference, 1896, at Trappes Observatory, Seine et Oise.



Plan of Rooms, 70 Victoria Street, Westminster, S.W.

Meeting Room.

19 Album containing Photographs of Clouds, taken by the Hon. R. Abercromby.

20 Three Albums containing Photographs of the Stations of the Royal Meteorological Society, taken by Mr. W. Marriott, 1884-98.

21 Testimonial Album presented to Mr. G. J. Symons, F.R.S., by the Fellows of the Royal Meteorological Society.
22 Large Cistern Barometer, made for the Meteorological Society of London in 1837, which cost forty guineas. The tube and cistern originally held 70 lbs. of mercury.
23 Meteorological Station at Isfield, arranged by Major H. King.
24 Exhibition of Anemometers by the Royal Meteorological Society, March 1882 (two photographs).
25 Map showing stations of the Royal Meteorological Society.
26 Chart prepared in honour of Dr. G. Neumayer's 70th birthday, containing Weather Charts for June 21, 1826.
27 Twilight and Afterglow Effects at Chelsea, 1884.
28 Photographs of Frost Scenes.
29 Photographs of Snow, Hail, Tornado Clouds, Water Spouts.
30 Photographs of Lightning.
31 Photographs of Floods, Cloud Burst, Waves, etc.

Fellows' Room.

32 Campbell Sunshine Bowl, exhibiting the effect of Sunshine at Kew Observatory during the half year ending June 21, 1897.
33 Campbell-Stokes' Sunshine Recorder.
34 Jordan's Sunshine Recorder (two patterns).
35 Fineman's Nephoscope.
36 Rain-Band Spectroscope.
37 Galton's Pocket Altazimuth Instrument.
38 Thomson's Portable Electrometer.
39 Specimens of Copper Tape for Lightning Conductors.
40 Aneroid.
41 Maximum and Minimum Thermometers, with plain tubes, as used in 1854.
42 Mercurial Thermometer, probably 100 years old.
43 Kew Standard Thermometer, No. 514.
44 Two Thermometers used in the inspection of the Society's Stations.
45 Bifurcated Grass Minimum Thermometer.
46 Casella's Mercurial Minimum Thermometer.
47 Symons' Earth Thermometer.
48 Black and Bright Bulb Thermometers *in vacuo*.
49 Clinical Thermometer, old pattern.
50 Kammerman's Sling Wet Bulb Thermometer, for use in frost.
51 Negretti & Zambra's Deep Sea Thermometer.
52 Thermometer as used on board ship for taking the temperature of the sea.
53 Metallic Thermograph, made by Mr. N. S. Heineken in 1837.
54 Whitehouse's Experimental Six's Thermometer, proposed to be adapted for recording purposes.
55 Negretti & Zambra's Turn-over Dry and Wet Bulb Thermometers.
56 Richard's Dry and Wet Bulb Thermograph.
57 Negretti & Zambra's Barograph and Thermograph combined.
58 Negretti & Zambra's new Self-Recording Rain Gauge.
59 Snowdon Rain Gauge.
60 Cathetometer for measuring the diameter of Rain Gauges.
61 Graduated Tubes for testing the accuracy of the Measuring Glasses of Rain Gauges.
62 Moisture Meter, or Scale for calculating at sight the Relative Humidity from the readings of the Dry and Wet Bulb Thermometers.

63 Alleged "Thunderbolts" exposed at the Meeting of the Royal Meteorological Society, March 21, 1888.
64 Models of Hailstones, 7 inches in circumference, which fell near Montereau, France, August 15, 1888.
65 Model of Hail Deposit on Snow.
66 Camera ($\frac{1}{4}$ plate) used for taking Photographs of the Society's Stations.
67 Arithmometer.
68 ROYAL CHARTER OF INCORPORATION granted to The Meteorological Society, January 27, 1866.
69 Letter from the Secretary of State informing the President that Her Majesty had been graciously pleased to grant the request of The Meteorological Society to adopt the prefix "Royal."
70 Seal of the Royal Meteorological Society.
71 Albert Medal, presented to Mr. G. J. Symons, F.R.S., by the Society of Arts.
72 Silver Medal awarded to the Meteorological Council at the International Fishery Exhibition, Berlin, 1880.
73 Gold Medal awarded to the Meteorological Council at the National Fisheries Exhibition, Norwich, 1881.
74 Silver Medal awarded to the Meteorological Council at the International Fisheries Exhibition, London, 1883.
75 Portrait of Henry Perigal.
76 Classification of Clouds for the Weather Observers of the Hydrographic Office, U.S.A.
77 Portrait of the Hon. Ralph Abercromby.
78 Photograph of the Summit of the Worcestershire Beacon above the level of fog.
79 Photograph of the Meteorological Station at Rousdon, arranged by Sir Cuthbert E. Peek, Bart.
80 Photographs of Clouds, by Mr. H. C. Russell, F.R.S., Sydney, N.S.W.
81 Photographs of Clouds, by Dr. A. Riggenbach, Switzerland.
82 Photographs of Clouds, by Mons. P. Garnier, Dr. F. G. Smart, etc.
83 Illustrations from the International and Dr. Hildebrandsson's Cloud Atlases.

LIBRARY.

84 Stevenson Thermometer Screen, fitted with Dry Bulb, Wet Bulb, Maximum and Minimum Thermometers.
85 Lantern Slides illustrating Meteorological Phenomena.
86 Dines's Pressure-Tube Anemometer, with registering tubes, to be used at Stone Ness Point, opposite Greenhithe, in connection with the Wind Force Experiments on H.M.S. *Worcester*.
87 Dines's Portable Pressure-Tube Anemometer.
88 Rainfall Map of India.
89 Prismatic Lunar Halo, by Dr. H. Dobell, Bournemouth.
90 Photographs of Damage by Wind, Lightning, etc.
91 Photographs of Damage by American Tornadoes.

SECRETARY'S ROOM.

92 Photographs of Kites, Wind Force Experiments, Halos, etc.
93 Plaque of Henry Perigal.

PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

May 17, 1899.

Ordinary Meeting.

FRANCIS CAMPBELL BAYARD, LL.M., President, in the Chair.

HERBERT ERNEST BELLAMY, Northam, Bideford ;
EDWARD CASE, J.P., The Hall, Dymchurch ;
FRANK JAMES GRAY, Assoc.M.Inst.C.E., 9 Upper King Street, Norwich ; and
JOHN EDWARD O'CONNOR, M.B., D.Ph., 1 Surrey Street, Lowestoft,
were balloted for and duly elected Fellows of the Society.

The following communications were read :—

"THE MEAN TEMPERATURE OF THE SURFACE WATERS OF THE SEA ROUND THE BRITISH COASTS, AND ITS RELATION TO THAT OF THE AIR." By H. N. DICKSON, F.R.S.E., F.R.Met.Soc. (p. 277).

"SOME PHENOMENA CONNECTED WITH THE VERTICAL CIRCULATION OF THE ATMOSPHERE." By Major-Gen. H. SCHAW, C.B., R.E. (p. 305).

June 21, 1899.

Ordinary Meeting.

FRANCIS CAMPBELL BAYARD, LL.M., President, in the Chair.

HENRY OSMUND BARNARD, Surveyor-General's Office, Colombo, Ceylon ;
AUGUSTINE MARSHALL, M.D., 145 London Road South, Lowestoft ; and
Capt. ROBERT HARLEY POTTER, 6 Alwyn Street, Aigburth Road, Liverpool,
were balloted for and duly elected Fellows of the Society.

The following communications were read :—

"HEAVY FALLS OF RAIN RECORDED AT THE OBSERVATORIES CONNECTED WITH THE METEOROLOGICAL OFFICE, 1871-98." By ROBERT H. SCOTT, D.Sc., F.R.S. (p. 317).

"A NEW SELF-RECORDING ANEMOSCOPE." By JOSEPH BAXENDELL, F.R.Met.Soc. (p. 326).

"AVERAGE HEIGHT OF THE BAROMETER IN LONDON." By R. C. MOSSMAN, F.R.S.E., F.R.Met.Soc. (p.330).

CORRESPONDENCE AND NOTES.

The Government Meteorological Organisations in various parts of the World.—Mr. F. C. Bayard has received communications from Gen. M. Rykatcheff and Dr. S. C. Hepites with reference to the figures which he gave in his Presidential Address showing the amount of the grants for Meteorology in Russia and in Roumania.

Russia.—Gen. Rykatcheff says that the total annual Government grant is 180,000 roubles, which includes the cost of the Central Physical Observatory (103,720 roubles). The amount in English money is therefore about £20,000, and not £44,922 as stated on pp. 76, 86, and 99.

Roumania.—Dr. Hepites says that the amount of the annual Government grant was £400 for the year 1884-85, but that for the current year 1899-1900 it reaches the sum of £3123.

Earth Temperatures at Meltham, Huddersfield.—Mr. C. L. Brook, F.R.Met.Soc., of Harewood Lodge, Meltham, near Huddersfield, who has taken earth temperature observations at 1 foot and 2 feet below the soil since 1885, has supplied the following tables of monthly means:—

TABLE I.—*Monthly Mean Temperatures of the Soil at 1 foot at Meltham.*

Years.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Means
	°	°	°	°	°	°	°	°	°	°	°	°	°
1885	35·8	39·2	38·7	42·3	46·2	53·7	57·3	54·8	51·7	45·3	41·6	38·3	45·4
1886	35·9	35·0	36·9	42·6	47·1	52·5	57·3	56·8	55·1	50·4	43·7	36·6	45·8
1887	35·0	36·5	37·1	41·3	46·1	55·3	59·5	56·2	51·9	44·2	39·9	37·2	45·0
1888	37·0	36·1	36·3	40·5	48·0	52·9	54·0	54·5	52·0	44·6	44·2	40·3	45·0
1889	36·9	37·2	37·9	42·2	51·3	57·0	57·6	56·5	53·8	47·0	43·9	38·3	46·6
1890	39·1	37·4	40·0	42·1	50·0	54·1	55·2	56·3	54·5	48·9	42·9	36·4	46·4
1891	33·9	37·3	37·3	40·0	46·5	53·5	57·0	55·4	54·0	47·8	41·9	38·1	45·2
1892	34·9	36·7	36·4	41·0	47·6	53·8	55·2	56·2	52·3	44·7	41·8	37·3	44·8
1893	34·1	38·5	39·9	45·4	51·6	56·0	58·4	59·3	54·0	48·7	41·4	39·6	47·2
1894	37·6	38·3	39·9	45·7	47·7	53·1	58·5	56·5	52·7	47·8	44·8	40·6	46·9
1895	34·6	32·2	35·6	43·7	50·3	55·2	57·7	58·3	56·0	46·7	43·0	39·0	46·0
1896	39·6	39·7	41·2	44·7	50·9	57·8	58·8	56·3	53·9	45·8	40·1	38·4	47·3
1897	36·1	37·6	40·6	42·8	47·9	55·4	58·5	58·7	52·8	48·1	45·7	39·9	47·0
1898	41·4	39·4	38·3	44·1	48·0	54·3	57·1	58·7	56·7	50·7	45·5	42·6	48·1
Average	36·6	37·2	38·3	42·7	48·5	54·6	57·3	56·8	53·7	47·2	42·9	38·8	46·2

TABLE II.—*Monthly Mean Temperatures of the Soil at 2 feet at Meltham.*

Years.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Means
	°	°	°	°	°	°	°	°	°	°	°	°	°
1885	37·0	39·6	39·5	42·2	45·9	52·5	56·1	54·8	52·1	46·4	42·6	39·7	45·7
1886	37·3	36·1	37·2	42·7	46·6	51·4	56·3	56·1	55·3	51·2	45·3	38·6	46·2
1887	36·1	37·4	37·9	41·6	45·7	53·7	58·4	56·3	52·8	46·1	41·5	38·6	45·5
1888	38·0	37·2	37·1	40·4	47·4	52·2	53·7	54·4	52·6	45·9	45·1	41·7	45·5
1889	38·0	38·3	38·4	42·3	50·1	55·8	57·3	56·4	54·4	48·2	45·3	39·8	47·0
1890	39·9	38·4	40·2	42·5	49·2	53·3	54·6	56·2	54·5	50·2	44·3	38·4	46·8
1891	35·3	38·0	38·0	40·2	46·2	52·3	56·3	55·3	54·3	49·2	43·4	39·6	45·7
1892	36·0	37·7	37·1	41·3	46·8	53·1	54·7	55·8	53·0	46·3	42·9	38·9	45·3
1893	35·3	39·0	40·2	45·0	51·0	55·3	57·8	58·8	54·8	49·8	43·0	40·9	47·6
1894	38·8	39·0	40·3	45·5	47·9	52·2	57·6	56·3	53·0	48·6	45·4	41·6	47·2
1895	36·2	33·6	35·9	43·2	49·5	54·1	56·8	57·7	56·0	48·4	43·6	40·2	46·3
1896	40·1	40·2	41·4	44·5	50·2	56·6	58·1	56·3	54·2	47·2	41·2	39·3	47·4
1897	37·1	37·6	40·9	42·9	47·7	54·3	57·7	58·5	53·3	49·1	46·5	41·0	47·2
1898	41·7	40·4	39·0	43·9	47·7	53·4	56·5	58·1	56·8	51·3	46·9	43·4	48·3
Average	37·6	38·0	38·8	42·7	48·0	53·6	56·6	56·5	54·1	48·4	44·1	40·1	46·5

"Sparking" of Lightning.—Mr. C. L. Brook, F.R.Met.Soc., had an interesting experience during a thunderstorm at Bidston, near Birkenhead, on June 28, 1899. He says:—

"The thunderstorm was decidedly severe, and one of the kind which does not apparently come from any particular direction, but seems to gather all round. About 4 p.m. I was standing about a yard inside the old-fashioned porch of Bidston church, waiting for the rain, which was falling in torrents, to abate. A flash of lightning passed very close indeed, right in front of the

porch opening; and I judged, from the fact that it appeared to be between me and the road on the north side of the church, that it could not have been more than ten yards away at the outside. At the same moment I heard the peculiar sound emitted by a dynamo when it is "sparking" badly, i.e. when numerous sparks are emitted at the point where the brushes rest on the commutator. The flash gave an exactly similar sound, but decidedly more intense.

"Another point is worth mentioning. A friend who was standing next me said, 'Did you see the zigzags?' I replied, 'Yes, but you know the modern idea is that there are no zigzags!' Nevertheless this flash left the impression of zigzags on the eye, apparently 2 or 3 feet long; and I have been wondering whether this is not really the case when one sees a flash very near, and that they appear as small sinuosities or irregularities when photographed several hundred yards off.

"I could see no trace of any damage done, but it was not altogether a pleasant experience."

Meeting of the International Meteorological Committee.—The Committee met at St. Petersburg from September 2 to 7; the meeting was a small one, only about half of the members being present. It was opened by the Grand Duke Constantine, who delivered an interesting address, in which he specially referred to the service rendered to meteorological science by A. Kupffer, the founder of the Russian climatological organisation. The reports of the various sub-committees were read and considered, and the following are the principal resolutions arrived at:—

On the report, by Prof. Rücker, upon terrestrial magnetism and atmospheric electricity, it was decided that the magnetic sub-committee should be maintained as a distinct organisation, under the direct supervision of the International Committee.

In reply to a question by Gen. Rykatcheff, Director of the Russian Meteorological Service, the Committee recommended that meteorological institutions should take part in observations of earthquake phenomena.

With regard to Antarctic exploration, the Committee expressed the opinion that it is highly desirable (1) that the results of these explorations should be completed by data from the observatories already existing in the southern hemisphere, and by those made on board vessels traversing the southern oceans; (2) that new meteorological stations should be established in the southern parts of the Antarctic regions, and especially that magnetic observations should be organised; (3) that magnetic determinations over the whole globe should be made simultaneously with those made during the expeditions.

With reference to the valuable researches of Dr. Hildebrandsson relating to the great centres of action of the atmosphere, the following resolution was adopted:—"The Committee appreciates the high interest attached to observations made in a regular manner in different regions which seem to possess special importance as to our knowledge of the general laws of the motions of the atmosphere."

Profs. von Bezold and Mascart drew attention to the proposed establishment of a very complete meteorological and magnetical observatory at the Azores by the Prince of Monaco, assisted by Capt. Chaves of the Portuguese navy, who has entirely devoted himself to the realisation of this undertaking.

On the question of the calculation of daily meteorological means, it was decided that if the exact formula $\frac{0+24}{2} + 1 \ldots + 23 : 24$ is not adopted, the midnight observation should be taken into account at the end of the day, as is already done at most stations, according to the formula $1 + 2 + 3 \ldots + 24 : 24$.

On the proposal of Dr. Hann to publish tables of diurnal range of temper-

ature for each country in a special form, the Committee, while appreciating the interest and importance of the proposal, expressed its opinion that, as the question possessed a general bearing, it should be examined by a sub-committee, which should determine the form of table to be adopted by all countries.

On the subject of the importance of actinometric observations, also brought forward by Dr. Hann, the Committee expressed the hope that the sub-committee for terrestrial and solar radiation would present a report upon that subject at the next International Congress. M. Violle submitted a note on the various methods employed for actinometric measurements.

On the proposal of Dr. Pernter as to the desirability of the restriction of observations with the wet-bulb thermometer and the multiplication of observations with the hair hygrometer, the Committee came to no decision, pending the presentation of a full report upon the question.

Dr. Paulsen, Director of the Danish Meteorological Institute, drew attention to the importance for weather prediction of the laying of a cable between Iceland and Europe, towards which the Danish Government and the Great Northern Telegraph Company were prepared to make a considerable annual subvention. The Committee fully recognised the importance of the proposal, and expressed its hope of the ultimate success of the project.

Profs. Neumayer and von Bezold made a proposal relative to the publication of an international periodical weather report, which should contain ten-day means from about a hundred stations. The Committee was of opinion that it would be desirable that a definite plan of the proposed publication should be prepared for examination by each meteorological service. A sub-committee, composed of MM. Pernter (President), Billwiller, Neumayer, Rykatcheff, Mohn, and Tacchini, was nominated for the purpose of considering the extension and improvement of international telegraphy for weather prediction.

Finally, it was decided that the International Meteorological Committee and the various sub-committees should meet in Paris in the year 1900, immediately after the Meteorological Congress which will take place on the occasion of the Exhibition. This Congress will probably be held during the first half of September.

We are indebted to M. Lancaster's summary in *Ciel et Terre* for the notice of this meeting.—*Nature*, October 19.

Indian Meteorological Service.—Mr. J. Eliot, F.R.S., in his *Report on the Administration of the Meteorological Department of the Government of India in* 1898-99, says that the Government has recently sanctioned a number of changes, which will come into effect during the present year. The following is a brief summary of the most important of these changes:—

(1) The transfer of the Colaba, Madras, and Kodaikanal observatories from the control of the Provincial Governments concerned to the Imperial Government, who have placed them under the general superintendence of the Meteorological Reporter to the Government of India (who has also been appointed Director-General of Indian Observatories).

(2) The transfer of the Madras Meteorological Office to the Astronomical Observatory, the direction of both offices being placed under a single officer, Mr. J. Llewellyn Jones, Professor of Physics, Presidency College, Madras.

(3) The reduction of the number of second-class observatories from 61 to 38. The work at several of these observatories was very unsatisfactorily performed, the 4 p.m. observations being frequently tainted with large errors. In order to make the remaining second-class observatories more useful and satisfactory, it has been decided to furnish them with Richard's barographs and thermographs giving a continuous registration of pressure and temperature.

(4) The appointment of an additional European officer in the Simla office to assist in the preparation of the Daily Weather Report and the issue of Storm and Flood Warnings.

(5) The discussion of the marine data collected during the past six years, and the publication of pilot charts for the Indian seas similar in general character to those issued by the Hydrographic Office, Washington, U.S.A. In order to carry out this work, and the discussion of certain accumulated data, a temporary extension of the Simla office was sanctioned.

It may be noted that the Government of India sanctioned the erection of a new office in the compound of the Alipore observatory during the present year. These new buildings will afford ample accommodation for the office and staff, and for the accumulating records of the Department. The buildings will be occupied this autumn, when the lease of the present building in 5 Russell Street, Calcutta, expires.

Notes on the Climate of Singapore.—As Singapore is situated so near the equator the temperature is naturally equable. The mean temperature of the year is as high as 80°, but it is only occasionally above 90° in the shade or below 70° at night. In ordinary comfortably warm weather the maximum of the day is from 85° to 87°, above that it begins to be hot; 89° is decidedly hot, and every degree above that is felt. I have seen 93° registered, but that is the absolute extreme. In the sun it is sometimes over 160°. The humidity of the atmosphere makes extreme temperatures difficult to bear. On a warm day, when the sun is not shining brightly, the feeling out of doors is very much that of the palm-house at Kew.

We are in the zone of frequent thunder and rain. The mean annual rainfall is a little over 90 ins. On a series of years, February is the driest month, and December the wettest: but the uncertainty of the weather is extreme—beyond even what is known in England. From our position, we are more exposed to the North-east Monsoon than to the South-west. In the early part of the North-east Monsoon, in November and December, we generally expect more or less continuous heavy rains, with much gloom, but little thunder. Sometimes in this weather the maximum temperature in the screen does not reach 80°, and then it is chilly. In my house I have occasionally seen it as low as 72° in the middle of the day, and it is then wretchedly cold. The exposed thermometer would probably be 6° or 7° higher. During the South-west Monsoon we have our greatest heats, tempered by frequent, but not constant, rains. These come often in the form of thunder-squalls, chiefly from the westward, whence they are known as "Sumatras." During the full prevalence of the South-west Monsoon,—say from June to September,—when some days pass without rain, a wind often prevails called the "Java" wind, blowing from South to South-east, which with old residents has a slightly feverish tendency. This wind continues blowing during the night, when winds that have no East in them generally drop, but it does not penetrate far inland. On account, probably, of the rapid evaporation produced by it, it gives a sensation of coolness; but if you move out of it you feel a burning sensation, and while it blows the temperature is always high and the nights especially oppressive. On clear still nights the dew is very heavy, sometimes giving quite a sharp feeling to the air at early morning.

There is a curious thing about these "Sumatras." In Crawfurd's *Dictionary of the Eastern Archipelago*, article "Singapore," they are said to occur usually between 1 and 3 a.m. That was certainly the case, according to my own observation, years ago; but I cannot say that now they occur oftener then than at any other time, and I think they are generally less frequent and violent. Another thing was that it was almost invariably clear from sunset till midnight, whatever storms there may have been in the course of the day (except in the occasional spells of constant rain already referred to). That is no longer the case; storms frequently come on at night. You may remember the great volcanic eruption of Krakatoa in the Sunda Straits, one effect of which was the

series of lurid sunsets which attracted the world. Well, this change in our climate, according to my own observation and that of others, dates from that time. Now, although I have for many years been an attentive observer of the weather, I do not profess to be a scientific observer, and will offer no theory. As regards this eruption, though we are between 400 and 500 miles north of the place, we both heard and felt the explosions here, and traces of the volcanic dust were found in the verandahs of houses facing the harbour.

I append an account of certain atmospheric explosions. A scientific friend here, who is Secretary of the Straits Branch of the Royal Asiatic Society, asked me to give him an account of these phenomena, possibly for insertion in the Journal. He told me that these explosions were not infrequent here, and that, so far as he had been able to ascertain, they had not been observed elsewhere. One not infrequently hears, in thunderstorms, reports like the discharge of ordnance, but it is curious that I have never had the opportunity before of so closely observing the phenomenon.

The following Table of Monthly Rainfall has been taken from the Principal Civil Medical Officer's Annual Meteorological Report, Straits Settlements :—

Mean Monthly Rainfall at Singapore, 1869 *to* 1898.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.
1869	3·93	3·23	3·37	9·23	9·19	6·81	5·42	12·31	3·13	5·11	8·24	20·66	90·63
1870	18·25	7·80	3·15	8·81	5·01	11·51	5·11	11·36	12·62	9·99	11·50	18·13	123·24
1871	11·05	7·69	12·95	4·85	3·96	4·59	12·42	6·69	8·97	12·36	11·36	12·56	109·45
1872	2·37	7·72	3·43	4·15	5·12	4·89	6·43	7·12	10·79	5·74	11·54	6·00	75·30
1873	7·16	9·57	9·74	10·54	5·50	4·81	3·55	6·08	3·00	7·93	12·56	5·16	85·60
1874	3·88	2·34	3·20	6·54	5·78	6·37	6·32	10·58	11·02	7·09	16·37	7·56	87·05
1875	2·91	7·02	16·92	6·47	4·09	9·53	4·26	8·36	8·24	8·29	11·37	6·50	93·96
1876	3·97	1·84	4·60	7·23	7·86	10·58	4·46	9·32	7·19	10·67	12·06	10·13	89·91
1877	2·89	5·74	5·01	1·37	4·05	11·47	5·70	4·00	2·74	2·09	5·24	8·07	58·37
1878	13·57	7·29	2·17	8·04	11·59	4·07	6·33	19·33	5·01	7·38	8·47	9·91	103·16
1879	19·18	9·14	9·81	6·61	10·86	7·07	5·51	8·94	5·54	14·96	8·37	10·15	116·14
1880	5·17	9·33	8·46	11·12	8·96	6·87	9·83	9·75	7·19	9·96	15·82	8·56	111·02
1881	13·35	2·01	9·03	5·21	9·40	4·03	6·35	5·77	5·51	10·54	9·48	13·32	94·00
1882	6·58	12·41	3·08	8·80	6·35	4·97	6·73	6·65	6·70	9·73	8·95	7·21	88·16
1883	3·18	1·98	6·71	7·23	7·11	5·21	3·12	3·37	10·29	7·96	6·22	7·76	70·14
1884	8·81	3·03	7·86	3·85	5·18	5·88	7·66	5·90	8·07	7·35	4·56	12·00	80·15
1885	1·63	5·54	1·41	3·89	6·30	9·39	4·46	3·03	4·34	3·67	10·57	13·75	67·98
1886	8·39	4·29	4·91	7·22	10·26	7·28	3·42	16·09	7·82	9·03	10·18	6·61	95·50
1887	10·75	11·09	6·50	7·49	7·98	8·76	9·16	14·32	7·08	7·47	9·56	12·81	112·97
1888	5·09	1·38	4·02	6·29	10·92	7·37	3·41	2·50	8·37	3·75	5·42	7·04	65·56
1889	5·36	6·81	3·02	4·41	7·41	5·21	9·62	6·16	9·46	6·26	14·00	6·33	84·13
1890	10·21	10·82	7·75	8·50	4·98	6·26	19·64	9·59	7·99	9·12	12·79	10·13	117·78
1891	9·46	6·15	10·07	8·90	6·35	5·59	4·92	8·69	6·61	6·99	8·91	5·84	88·48
1892	7·53	4·05	10·69	6·54	11·69	2·89	5·95	8·62	5·96	8·07	9·08	18·63	99·70
1893	27·47	3·88	5·62	8·43	2·82	5·65	9·48	9·78	4·78	12·85	7·38	13·27	111·41
1894	8·13	0·98	13·26	5·61	4·85	7·26	6·50	9·98	5·42	4·42	8·66	6·17	81·24
1895	6·04	2·49	6·40	11·48	7·23	6·45	9·91	6·67	4·75	10·77	12·49	13·46	98·14
1896	3·51	5·49	6·29	3·54	4·01	6·09	4·79	6·98	3·44	9·05	7·29	13·61	74·09
1897	4·29	17·60	10·83	7·79	9·46	5·32	6·59	7·75	5·81	11·55	8·19	6·40	101·58
1898	8·28	9·15	10·55	9·28	5·32	6·61	10·10	5·50	8·97	12·35	7·74	12·34	106·19
Mean	8·08	6·26	7·03	6·98	6·99	6·63	6·91	8·37	6·89	8·42	9·81	10·33	92·70

On September 12, 1898, between 6 and 7 p.m., when it was nearly dark, I was going home from town in a carriage, and when about three-quarters of a mile from home I saw a flash in front, and there was a loud report which caused my pony to start forward. On reaching my house I found that the

ladies of my household had been much startled by the explosion. Two of them had been at the entrance-gate, standing facing towards the town, while two others were walking from the direction of the town, and were nearly a quarter of a mile from the house. To the former two a flame-coloured flash seemed to fall in front of them ; to the latter two, a bright light seemed to be thrown in their faces, and the loud report was instantaneous. These two afterwards detected something like a sulphurous smell, and all felt a sensation like an electric shock. There had been some distant thunder and rain shortly after noon. It had afterwards been bright but stormy looking, and though clouds were gathering in the evening, there had at that time been no thunder or lightning ; shortly afterwards there was heavy thunder near, followed by a copious shower.

On October 14, 1898, there was a very severe thunder-squall—strong wind, violent rain, and much thunder not very distant. It came on suddenly about 7 p.m., as we were going down to dinner. The dining-room opens on verandahs front and back. As I was about to take my seat at the end of the table facing the back of the house, I saw an explosion in the air, like that of a fire-ball or bomb, probably four or five feet above the ground, and there was a loud bang. The light appeared greenish white. There is no doubt that the explosion was in the back garden, a few feet behind the house, as it was also located there by some neighbours whose line of sight was at right angles with mine. This seems, however, to have been much less intense than the former explosion. No débris were found.—ARTHUR KNIGHT, Grassdale, River Valley Road, Singapore, *April* 20, 1899.

Rainfall of the Caucasus.—Mr. V. Dingelstedt, in a paper on "The Hydrography of the Caucasus," published in the *Scottish Geographical Magazine*, June 1899, gives the following particulars about the rain and the snowfall of that district :—

The great majority of the streams of the Caucasus are dependent upon the direct supply from rain or surface springs, the glaciation not being extensive, and calcareous rock capable of retaining moisture in deep-seated springs being of comparatively small extent. There are now in the country 141 stations where, under the general supervision of the Physical Observatory of Tiflis, the precipitation is recorded. Thirty-six of them are in the Northern Caucasus, the rest in Transcaucasia. Thus there is one station for about 2500 square miles in the former, and for about 900 square miles in the latter part of the country. For a hilly country they are certainly far from sufficient for any accurate observation of so complex a phenomenon. In Switzerland, over an area which is only one-eleventh of that of the Caucasus, there are 300 rain-gauges, and these are not considered sufficient. But we obtain nevertheless a tolerable approximation to the truth for the region we are considering. The rain is very unequally distributed. On the eastern shore of the Black Sea, in Sochi and Batum, fifteen times as much rain falls as on the Aras, in Kulp, in Aralykh, and Boasta ; the extreme numbers being 93·3 ins. annually in the former, and only 5·4 ins. in the latter case.

The mean annual quantities, taken from official sources, are as follows. The numbers in parentheses indicate the altitude in feet :—

From 59	to 93·1	ins.,	Eastern shore of the Bla[illegible]
,, 49	,, 59	,,	Kutais, Lailashi (23[illegible] (5501
,, 39	,, 49	,,	Kobi (6578 ft.), [illegible]
,, 29·5	,, 39	,,	Alaghir (2031 [illegible]), Kliuch [illegible]
,, 19·5	,, 29·5	,,	Mozdok, [illegible] (524[illegible] Bor[illegible] ([illegible]

From 15·75 to 19·5 ins., Temriuk, Ghelenjik, Petrovsk, Tiflis, Akhaltsikh (3379 ft.), Kars (5715 ft.), Novobaiazet (6385 ft.).
,, 12 ,, 15·75 ,, The steppes north of Piatigorsk, Akhty, Kusary, Alexandropol (5000 ft.), Erivan (3258 ft.), Ordubat (3120 ft.).
,, 8 ,, 12 ,, Kizliar, Kaghyzman (4619 ft.), Jagry (3445 ft.), the lowlands of the Kura and Aras.
Under 8 ins., on the North Caspian shore (Boasta) at the foot of Ararat, Aralykh (2753 ft.).

What is surprising in these numbers, and, certainly, not to be accepted without some caution, is the small influence exercised in some cases by the altitude of the points of observation. We have, it is true, some high stations, such as Gudaur and Kobi, which indicate an abundance of precipitation; but, on the other hand, there are points situated as high as Kars, Novobaiazet, Alexandropol, Kaghyzman, and Jagry, which rank as to the quantity of their rainfall with stations such as Temriuk, Ghelenjik, Petrovsk, Akhty, and others, which are at sea-level, or even a few feet below it. Perhaps the discrepancy is to be attributed to the difficulty of accurate observation of the snowfall, which is included in the evaluation of mean annual rainfall, and which is more frequent in the mountains. It is also not easy to understand the considerable differences in the indications of the rain-gauge at points so near and so similarly situated as, for instance, Divnoe, 11·3 ins.; Medviezhie, 16·7 ins.; Abedati, 71·4 ins.; Kutais, 53·1 ins.; Mozdok, 19·6 ins.; and Naursk, 10·2 ins.; but the rain is capricious.

Advancing from the north to the south, the rainfall increases till it arrives at its maximum in lat. 43°–42°, in which extends the main chain; then it quickly decreases. The mean annuals according to the latitude are as follows:—

			ins.
Between Lat.	46°–45°,	mean annual rainfall	18·55
,, ,,	45 –44	,, ,, ,,	23·00
,, ,,	44 –43	,, ,, ,,	23·50
,, ,,	43 –42	,, ,, ,,	37·00
,, ,,	42 –41	,, ,, ,,	27·50
,, ,,	41 –40	,, ,, ,,	14·50
,, ,,	40 –39	,, ,, ,,	13·00

From west to east the rainfall rapidly increases; from 20 ins. annually between the meridians 37°–38° east of Greenwich, it becomes 21·5 ins. at Long. 38°–39°, and 52 ins. at Long. 39°–40°. Then it maintains an average of 37 ins. eastwards to 43°, after which it decreases considerably, the annual mean between Long. 43° and 50° being about 20 ins.

In respect of precipitation, the country may be roughly divided into two regions, the well-watered and the dry. The first embraces principally the south-eastern basin of the Black Sea; it has an area of about 72,600 square miles, and a rainfall from 25·6 ins. up to 93·3 ins. a year, with an average of 37·5 ins., which gives annually about 43 cubic miles. The second, eastern, part, appertaining mostly to the Caspian basin, has an area of about 109,000 square miles, or 60 per cent of the whole; it has a mean annual rainfall of 20 ins., which gives a volume of water of about 34 cubic miles. The total volume of water the country receives annually is therefore 77 cubic miles, corresponding to an average rainfall for the whole country of 27 ins. annually.

It rains rather more in the spring and summer than in the other seasons, the proportion being as 58 to 42 per cent in the Northern Caucasus, and 54 to 46 per cent in Transcaucasia. On the south-eastern shore of the Black Sea (Batum, Artwin), as also in Lenkoran, most rain falls in the autumn; whilst in the vicinity of the Sea of Azof the winter is the wetter season.

We have no very exact data concerning the snowfall, which, in consequence of defects in the apparatus used to gauge it, is to be considered as a rather

disturbing element in the evaluation of the precipitation. In the Northern Caucasus, and at high levels, it snows from November to March; it snows but very little, and seldom, in the low plain of the Kura and Aras, and scarcely ever at the south-eastern corner of the Black Sea.

The perennial snow-line is at an altitude of 9600 ft. in the western part of the main chain, at the sources of the Rion; at 10,500 ft. in the Central Caucasus, from the Passimta to Barbalo; and at 12,200 ft. in the eastern part of the chain, from Barbalo to the Shakh-dagh, thus continually rising from west to east. On the southern slope the snow-line descends some 1000 to 1500 ft. lower than on the other side, which is owing to the dryness of North and North-east winds, arrested by the "lateral" chain, and thus despoiled of the little humidity they may contain. The main chain is covered with perennial snow for some 200 miles, that is, for about one-fifth of its length. But we should by no means consider the region of perennial snow as of fixed extent; for the snow-line is not a definite immoveable line, as was well explained by Dr. E. Brückner in the *Meteorologische Zeitschrift*, January 1887, but one which varies both in space and time.

Temperature of the Caspian Sea.—In the *Pilot* of the Caspian, compiled by Captain Pushchin, it is stated that between Tiub-Karagan and Krasnovodsk a sudden fall of temperature is frequently met with in summer near the shore, and it would appear from the records in the *Pilot* that the summer temperature is lower on this side than in the middle of the sea or on the western side. Captain Pushchin ascribes the phenomenon to rapid evaporation and submarine currents, while G. Philipof refers it to cold springs. Being sent in 1897 to take part in an investigation of Karabugas Bay, Mons. J. B. Spindler took the opportunity of making observations on the temperature. On a voyage between Baku and Krasnovodsk in May he found the surface temperature 63°·9 in the west, 64°·2 in the middle of the sea, and 67°·6 in the eastern part, while the salinity was 1·38 per cent, 1·42, and 1·42 respectively, with a South-east wind or calm. Again, in July, the temperatures were 75°·7, 72°·9, and 70°·5, while the corresponding salinities were 1·39, 1·43, and 1·44, with a North-west wind or calm. Thus greater salinity was associated with higher temperature in the former case, and with lower temperature in the latter. Hence M. Spindler concludes that the variation of temperature is not due to evaporation, but to the direction of the wind. Between Krasnovodsk and Karabugas he observed in May a temperature of 63°·9, and in July of 62°·4, the salinity in both months being 1·43 per cent. In the former month the wind was South and West, while the observations in July were made after feeble North-west and East winds. The wind may produce the phenomenon either by sweeping the surface water away from the coast and allowing the colder water from below to well up, or by producing currents along the coast, which, diverted to the right by the rotation of the earth, make room for the colder water to take their place. According to this theory, the temperature of the water should fall at the eastern shore during East winds, and with Northerly or North-westerly winds that give rise to currents on the water from the north, while on the western shore the effect should be produced by South-east and South winds and by Westerly winds, the latter driving away the surface water. And these conclusions agree with the observations. In summer the prevailing wind in the Caspian basin is the North, and therefore the temperature should be lower off the eastern shore than off the western.

M. Spindler adds a few remarks on the temperature of the lower layers. The only earlier observations were those of Grimm in the southern basin, made with imperfect instruments, and his temperatures appear to be too high. M. Spindler's were made early in July in the southern basin, 60 miles from

Baku. The temperature, at the surface 72°·9, sank rapidly below 10 fathoms, and below 200 was constant at 21°·2. In this bottom layer the salinity was a little greater than on the surface, but not more than at the surface off the eastern shore, where it is generally greater than in the centre and western parts. Hence there is a slight movement of water between the surface and the depths, and this explains the absence of sulphuretted hydrogen from the deep waters of the Caspian, whereas in the Black Sea, where the salinity constantly increases, the lower layers are polluted with this gas.—*Izvestiya* of the Russian Geographical Society, vol. xxxix. No. 2.

Temperature of the Floor of the Ocean, and of the Surface Waters of the Ocean.—In the *Geographical Journal* for July, Sir John Murray has a paper on this subject, in which he says that our knowledge of the temperature of the floor of the ocean is derived from direct observations in the layers of water immediately above the bottom by means of deep-sea thermometers, from the electric resistance of telegraph cables resting on the bed of the great ocean basins, and from the temperature of large masses of mud and ooze brought up by the dredge from great depths. All the temperatures recorded up to the present time in the sub-surface waters of the open ocean indicate that at a depth of 100 fathoms all seasonal variation disappears. Beyond that depth there is a constant, or nearly constant, temperature at any one place throughout the year. In some special positions, and under some peculiar conditions, a lateral shifting of large bodies of water takes place on the floor of the ocean at depths greater than 100 fathoms. This phenomenon has been well illustrated by the researches of Prof. Libbey, off the east coast of North America, where the Gulf Stream and Labrador current run side by side in opposite directions. This lateral shifting cannot, however, be called seasonal, for it appears to be due in most instances to violent storms, or strong off-shore winds, bringing up colder water from considerable depths to supply the place of the surface drift, so that this colder water covers stretches of the ocean's bed which, under normal conditions, are overlaid by warmer strata of water.

From the point of view of temperature, the whole floor of the ocean may be divided into two regions:—

(1) A deep-water region, in which there is a constant, or nearly constant, temperature in the water over the bed of the ocean at all times of the year at any one spot; and

(2) A shallow-water region, in which the sea bed is subject to periodical variations, or occasional variations, of the temperature through changes in the overlying water.

The investigations recorded in this paper indicate that the first region occupies over 90 per cent, while the second occupies less than 10 per cent, of the floor of the ocean.

All the figures, as well as an examination of the three maps accompanying Sir John Murray's paper, bring out the striking contrast between the temperature conditions on the surface and at the bottom of the ocean. Of the entire sea floor, 92 per cent is overlaid by water having a temperature under 40°, while of the entire surface of the ocean only about 16 per cent has a mean temperature under 40°.

From the data available, a preliminary attempt was made at a rough estimation of the proportion of the entire bulk of water in the ocean with a temperature below 40°. The result arrived at is that probably more than 80 per cent of the whole mass of ocean water has a temperature of under 40°, while no less than 20 per cent has a temperature exceeding 40°.

The maps and tables also suggest some relations of much interest to the biologist and the geologist. Wherever the waters of the ocean have a tempera-

ture exceeding 60°, a more abundant secretion of carbonate of lime by marine organisms takes place than in areas where lower temperatures prevail. The massive coral reefs are all situated along shores where these high temperatures prevail, and are made up of the shells and skeletons of organisms which, when alive, are attached to or creep over the bottom, and are now called benthonic organisms. The remains of pelagic or planktonic organisms make up an extremely small part of a true coral reef. From the foregoing investigation, it appears that an area of only about 4,000,000 square miles, or three per cent of the floor of the ocean, presents conditions of temperature favourable for the vigorous growth of coral reefs and of those organisms which require a temperature of 60° all the year round.

On the other hand, more than half of the surface of the ocean has a temperature which never falls below 60° at any time of the year, and in these surface waters of high temperature there is an abundant secretion of carbonate of lime by pelagic molluscs, pelagic foraminifera, coccospheres, and rhabdospheres, and of silica by radiolaria and diatoms. The dead shells and skeletons of these surface or planktonic organisms fall to the bottom of the ocean, and make up the major part of the deep-sea deposits known as pteropod, globigerina, and radiolarian oozes, as well as a very considerable part of the red-clay and blue-mud deposits in deep water. But the temperature at the bottom where these deposits are being laid down is very low, so that there are mingled in the same marine deposits now forming over a large part of the earth's surface the remains of animals that lived during their whole life in a temperature between 70° and 90°, and the remains of animals that lived during their whole life at a temperature of 1°, 2°, or 3° above the freezing-point of fresh water. The bearing of this on a study of the conditions under which many fossiliferous marine rocks have been laid down is evident.

RECENT PUBLICATIONS.

British Rainfall, 1898. Compiled by G. J. SYMONS, F.R.S., and H. SOWERBY WALLIS, F.R.Met.Soc. 8vo. 319 pp. 1899.

The number of perfect rainfall records published in this volume is 3404, being an increase of 86 upon the previous year. The rainfall in 1898 was greatly deficient over England and Wales, but was much in excess over Scotland. The largest rainfall was 240·05 ins. at Ben Nevis Observatory, and the least 13·04 ins. at Barking Outfall, Essex. In addition to the rainfall statistics and notes on the meteorology of 1898, the volume contains several papers and reports. The question "What constitutes a dry civil year?" is discussed; and the answer given is, "A year with a tenth less than the average," and, if the deficiency exceeds a quarter of the average, the year should be called "Very dry." A description is also given of the self-recording rain-gauges designed by Mr. W. J. E. Binnie, Mr. W. H. Dines, Mr. S. P. Fergusson, Prof. G. Hellmann, MM. Légé et Cie, Messrs. Negretti and Zambra, Mons. J. Richard, and Mr. G. B. Tomes.

Journal and Proceedings of the Royal Society of New South Wales for 1898. Vol. XXXII. 8vo. 1898.

Contains the following papers bearing on meteorology:—"Current Observations on the Canadian-Australian Route": by Capt. M. W. C. Hepworth (12 pp.).—"Waterspouts on the Coast of New South Wales": by H. C. Russell, F.R.S. (18 pp. and 8 plates). On May 16, 1898, in the space of five hours,

fourteen complete waterspouts, and six others more or less incomplete, were seen off Eden, on the coast of New South Wales. In addition to this, Mr. Russell gives an account of thirty-seven other waterspouts seen off the coast of New South Wales between 1888 and 1898. The plates give illustrations of many of these waterspouts.—"Current Papers, No. 3": by H. C. Russell, F.R.S. (11 pp. and 2 plates). In his two previous papers the author recorded 200 Current papers, and this paper adds another 167 to the list.—"Engineering Construction in connection with Rainfall": by J. I. Haycroft (20 pp.).

Meteorologische Zeitschrift. Redigirt von Dr. J. HANN und Dr. G. HELLMANN. July—September 1899. 4to.

The principal articles are:—"Ueber das Harmattanphänomen in Togo": von A. v. Danckelman (17 pp.). This is a paper on the occurrence of Harmattan winds in German Upper Guinea. The accounts of three different observers are given. The chief characteristics are North and North-east winds; great dryness, which is at times suddenly interrupted; great prevalence of dust haze; and remarkable depression of temperature towards morning. These observers maintain that it is clear that the wind does not come from the Sahara, but is essentially a local phenomenon, the dust being stirred up by local gusts. One remarkable fact is that the humidity is not by any means very low. Baron von Danckelman does not think that these observers have fully proved their case, and attributes the Harmattan in great measure to winds from the Western Soudan. He admits that the hygrometrical conditions do not always indicate great dryness, but says that no explanations are given of the sudden changes in dryness. The authors cited attributed the dryness to descending air currents; but the Baron points out that this only occurs when North or North-east winds have prevailed for a long time, and is never observed when the wind is variable.—"Arbeitsvorgänge bei auf- wie- absteigenden Luftströmen und die Höhe der Atmosphäre": von A. Möller (4 pp.). This is a mathematical discussion of the phenomena of ascending and descending currents.—"Die Strömungen der Luft in den barometrischen Minima und Maxima": von Dr. P. Polis (31 pp.). This is an abridgment of a paper in *Aus dem Archiv der Deutschen Seewarte.* Dr. Polis has taken six stations: Furnes (in Belgium), Aix-la-Chapelle, Breslau, Carlsruhe, Höchenschwand (in Black Forest), and the Schneekoppe, and examines the Daily Weather Charts of the *Deutsche Seewarte* for each day. He finds that the stations more to the north are more frequently in the region of a cyclone than of an anticyclone, the reverse being the case with the southern stations, Carlsruhe and Höchenschwand. He then proceeds to calculate the angle of inclination of the wind to the isobars in each case, as the Rev. W. Clement Ley used to do. He finds that in certain cases Mr. Ley's conclusions are confirmed, but in others not. Dr. Polis states as his first principle that the magnitude of the angle depends on friction, but the force of the wind and the contour of the ground modify this. In Europe in general, East winds have a small, and West winds have a large, angle. As regards wind force, the Southerly winds are strongest in cyclones on the coast; the Northerly are strongest in inland cyclones. Dr. Polis goes on to treat of the mechanical origin of cyclones and anticyclones, and of the causes of their translation over the earth's surface, and winds up the paper with a discussion of the various angles of inclination at various distances from the centres of the respective systems. The paper merits very careful study from those who take an interest in the generation of atmospheric disturbances.—"Einige Ergebnisse der Aufstiege der österreichischen Luftballons bei der VI. internationalen Simultanfahr am 24 März 1899": von J. Valentin (8 pp.). Two balloons were sent up from Vienna on March 24—one manned, the other

not—within an hour of each other. They reached about the same height; but while the former came down in Hungary, the latter descended in Russian Poland, between Lublin and Warsaw. The observations show a remarkable difference from those of the other balloons sent up on that day. They both showed frequent oscillations of temperature at about the same level, and also recorded a decidedly warmer stratum of air than any of the other international balloons in Northern Europe met with. The whole results are carefully digested in the paper.

Monthly Weather Review. Prof. CLEVELAND ABBE, Editor. Prepared under the direction of WILLIS L. MOORE, Chief, U.S. Weather Bureau. April—July 1899. 4to.

Among the reports and contributions are the following articles:—"A Talk on Elementary Meteorology": by G. M. Davison (5 pp.).—"Normal Precipitation in the region of the Great Lakes": by A. J. Henry (2 pp.).—"The present state of Long-range Forecasting" (1 p.).—"The Prediction of Tornadoes and Thunderstorms" (1 p.).—"The Climatology of the Isthmus of Panama, including the temperature, winds, barometric pressure, and precipitation": by Gen. H. J. Abbot (6 pp.).—"Special Report on the Flood in the Brazos River Valley, Texas, June 27 to July 15, 1899, with notes of previous overflows of the Brazos": by J. M. Cline (4 pp.).—"Sudden Oscillations in Lake Level-pressure Waves": by A. J. Henry (2 pp.).—"Effect of Wind on Catch of Rainfall" (2 pp.).

Symons's Monthly Meteorological Magazine. July—September 1899. 8vo.

The principal articles are:—"Meteorological Extremes" (5 pp.). The Editor proposes to give in the magazine a list of extremes of pressure, temperature, wind, rain, etc. The first article is devoted to pressure. It appears that the highest recorded reading of the barometer, reduced to sea-level, was 31·780 ins. at Irkutsk, Siberia, on January 14, 1893; and the lowest was 27·135 ins. at False Point, on the Coast of Orissa, India, on September 22, 1885.—"Effect of the Moon on Temperature": by H. A. Hazen (2 pp.).—"Ozone": by S. H. Miller (1 p.).—"The Moon and the Weather": by W. H. Dines (1 p.).

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THE END OF VOLUME XXV.

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MEZZANINE